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ABSTRACT

This document provides teachers with sources of useful information and new ideas about the high school chemistry laboratory program. Chapters included are: (1) "Introduction" describing the philosophy and specific objectives of this project; (2) "Importance of Laboratory Work"; (3) "Chemistry Lab Outline" listing titles of experiments in four textsbooks; (4) "Inventory" discussing a chemical management system; (5) "Information on Some Chemicals Used in Schools" including glossary and chemical list; (6) "Treatment of Hazardous Wastes" providing information on commercial hazardous wastes disposal and its alternatives; (7) "Hazardous Materials Spills" describing teacher's action when a spill occurs; (8) "Experimental Design" suggesting some ideas on experimental modification such as mini-scale experiments, micro-scale experiments, or micro-scale glassware with lists of the suppliers; (9) "Representative Modifications of Popular Experiments" providing several exemplary experiments; (10) "Suggested Safety Committee Program"; (11) "Student Involvement" providing strategies for developing involvement; (12) "Bibliography" including books, manuals, and phone numbers of resources; and (13) "Postlude." (YP)

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Reduction of Hazardous Waste

from

High School Chemistry Laboratories

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Sponsor -

Pollution Prevention Pays Program
North Carolina Department of
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DISCLAIMER

No chemical procedure can be guaranteed "safe". All experiments recommended in this manual appear to present minimum hazards. However, there is no guarantee, expressed or implied, that an experiment or procedure will not cause injury. Each teacher selecting an experiment should try it out under carefully controlled conditions before using it as a class exercise. Any necessary safety precautions should be added to the material given to the students. Activities which cannot be deemed safe for students should be altered in their delivery mode, have additional safety factors added or be deleted totally.

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I. Introduction

Sponsor

The Pollution Prevention Pays Program of the North Carolina Department of Natural Resources and Community Development provided the funds for this activity. Their support is greatly appreciated.

Background

High school teachers throughout the country are perplexed! They are told to teach ever more challenging courses in chemistry but are warned that the use of chemicals known to be hazardous may result in serious liability problems should an accident occur in their laboratories.

Regulations covering the use and disposal of chemicals are proliferating, but teachers are given little guidance and less time and money to properly implement them. Facilities for high school laboratories and chemical storerooms are generally inadequate and rarely secure.

Since 1983, a general high school safety manual, the **"STOP"** Manual has been available from the North Carolina Department of Public Instruction. Dr. William Spooner has produced countless local and state-wide workshops to explain the contents of the manual and to generally inspire teachers about the need for proper safety practices in the schools. This manual needed up-dating in light of the most recent regulations, particularly in the areas of hazardous materials and their disposal.

Present Project

A document addressing the problems of hazardous materials and giving the busy high school chemistry teacher straightforward, practical and up-to-date recommendations on how to cope with the ever more complex situation of hazardous materials in the school is needed.

This document is important to the teachers, students and citizens of North Carolina because of the quantities and diversity of hazardous materials currently found in our schools, the waste that is generated yearly, and the money spent on the purchase of large quantities of unnecessary chemicals. The excess chemicals on our shelves are increasing each year. The monetary and environmental costs of their disposal continue to escalate.

Implementation

From the beginning, it has been our strong belief that any document that would so closely affect the classroom teacher should be produced only by experienced high school chemistry teachers. We therefore selected six teachers from locations widely dispersed throughout the state (see "Participants", p. 5). These teachers were chosen on the basis of recommendations and personal knowledge of their abilities and accomplishments. They were brought to the Department of Chemistry on the campus of North Carolina State University for an intensive one week workshop during July 1987. The teachers sifted through masses of material and produced the present document. A draft document was presented at the 1988 North Carolina Science Teacher's Association Convention in Asheville and was extensively reviewed by teachers and other professionals.

Two nationally known experts were added to the workshop as consultants. The first, Dr. Kenneth L. Williamson of Mt. Holyoke College, a member of the National Academy of Sciences panel that produced the landmark document "Prudent Practices for the Disposal of Laboratory Waste" and author of "Macroscale and Microscale Organic Experiments". Also, Dr. Jack Gerlovich, from the Iowa State Department of Education, a frequent speaker on hazardous waste issues in the school and author of the important new micro-computer program "The Total Science Safety System for Grades 7-14". Mrs. Helen Stone of Greensboro, a highly respected and widely acclaimed High School Chemistry teacher, was retained as a consultant and advisor to the program. Dr. William Spooner, Division of Science, NC Department of Public Instruction served as a consultant to the program that was directed by Dr. George H. Wahl, Jr., of the NCSU Department of Chemistry.

Philosophy

The goal of this document is to provide teachers with sources of useful information and some new ideas about the high school chemistry lab program. Most importantly, we believe that chemistry students need quality lab time as an integral part of their program, and this experience should be delivered in the most environmentally sound manner possible.

All lab experiences must be carefully selected by the teachers. One important criterion in selecting a lab activity should always be *" Does the benefit exceed the risk?"*. Those responsible for making decisions on which substances are 'safe' for school use must consider many factors: 1.) grade level ; 2.) subject for which it is being used; 3) the academic and safety background of the teacher using it; and, 4) the physical facilities, *i.e.* availability of proper safety equipment. Educators can only make such determinations if they have carefully studied the health and safety hazards present in their labs.

It is imperative that all safety equipment be functional and immediately available. The minimum critical items include:

- Safety Glasses for students and teachers
  (*as described in* **ANSI** Z87.1; 1979)
- Fire Extinguisher
  (*appropriate type and capacity*)
- Fire Alarm
- Eyewash
  (*continuous flow; not, bottle type.*)
- Fire Blanket

Early each year, teachers should simulate one or more emergencies with the students to insure that all equipment is working and that the students and teachers know how to use it.

Due to the frequent turnover of teachers, and irregular funding, an unwieldy inventory of chemicals is often accumulated. Since most teachers find themselves overworked, they have little opportunity to reduce this backlog of chemicals. Furthermore, they are not given the appropriate equipment, funding or assistance to properly manage these inherited chemical problems. To simplify this process and make updates easier, the Inventory section of this document describes the process and the computer software available.

We strongly believe that high school chemical holdings need to be carefully examined in light of current experimental needs and current regulations. Unnecessary and unknown chemicals should be properly disposed of with assistance from the state. All currently needed chemicals must be kept in a secure, well-ventilated area, and only in reasonable quantities.

Most importantly, we also recommend the reduction in scale of most, if not all, current experiments. This "Micro-Scale" approach will permit students to obtain as much laboratory experience (and probably more!) with reduced chemical cost, risk and hazardous waste problems. In short, when speaking about the **quantities of chemicals in the lab -**

Less is Better

Some administrators and school boards have considered the extra trouble of working with chemicals to be too great and have significantly decreased the time devoted to chemistry laboratory. We believe this to be a great mistake! Chemistry is an experimental science. Without the lab, the course is no longer a chemistry course. Teaching chemistry without lab is like teaching driver's education without on-the-road experience. Hands-on experimentation with chemicals has no substitute and must continue to be an integral part of the high school chemistry course.

Specific Objectives

The objectives of this project are to:

1) Assess the current chemical inventories found in schools - What chemicals should be removed; and how can teachers remove these chemicals in a safe economical and appropriate way?

2) Compile an annotated list of chemicals that can be used to emphasize some of the hazards of common chemicals.

3) Prepare an annotated list of laboratory experiments from manuals which accompany state adopted text books.

4) Minimize the quantities of chemicals used in labs in order to reduce teacher and student exposure to chemicals and the accumulation of hazardous waste.

5) Recommend " In-House " treatment of some chemicals as an alternative to expensive commercial disposal.

6) Encourage safer, more effective lab work and lab environments in schools.

Every school needs a chemical management system. Through such an effort, the quantities of hazardous and unwanted chemicals found in schools will decrease. This decrease will benefit teachers, students, and the citizens of North Carolina. The need for large chemical purchases and expensive, specialized hazardous waste removal will significantly decrease. When teachers exhibit careful use and disposal of chemicals, the awareness of our young citizens about their environmental responsibilities will also increase. We hope this document will guide the development of a safer and more effective laboratory program.

In all of these activities, strong support of the school administration is vital for success.

II. Importance of Lab Work

Many centuries ago, an old Chinese philosopher said:

"I hear and I forget,
I see and I remember,
I do and I understand."

This is the credo of anyone in science. Doing experiments and field work is the grist of science. George W. Tressel, Director of the National Science Foundation Division that develops materials for science instruction, decries the use of a "Tutor in a Box" or a computer simulation of a laboratory experiment. "This is no substitute for a real lab. It's hard to learn science without actually touching it, doing it, seeing how the experiment really comes out. There's a problem with the weakening of hands-on science education."

The North Carolina Teacher Handbook for Science 9-12 in its purpose and overview recognizes that *"The child's first experience with science, from the earliest grades, should involve aspects of experimental inquiry "* (p. 28). Further, this emphasis on the scientific process is reinforced by the philosophy that, *"Instruction should be largely laboratory-oriented, stressing scientific methods through application of process skills "* (p. 29). However, with new knowledge of hazards in the lab and with an increase in litigation against teachers and school systems, there is often a tendency to reduce the amount and quality of laboratory experiences offered.

Such a return to a more content-oriented, textbook approach to science would eliminate or severely reduce three fundamental elements in the total development of the science student. These elements are hands-on experience with science, acquisition of science process skills, and practice with higher order thinking skills. These three elements are fundamental since science is a process of examination, classification and description, rather than a set of facts and theories to be memorized. Laboratory activities stress these fundamental elements and encourage the student to move from a knowledge of the known into an understanding of the unknown.

The first element, **hands-on experience with science**, is necessary to develop within the student an appreciation of science as a real-world study. Laboratory activities provide an opportunity for the history and theory of science to become tools for understanding. In this way, a study of science becomes a process for real problem solving rather than simply a body of facts and vocabulary to be mastered.

The second necessary element in the total development of the science student, **the acquisition of science process skills**, is also fostered by a laboratory-based study. Through such study the student is encouraged to observe, predict, hypothesize, classify, control experimental variables, interpret data, infer, develop models, measure, define, and communicate results. These are skills that are difficult to develop in classroom activities of lecture and practice drill. The best vehicle for their integration into the curriculum is the laboratory.

Finally, **higher order thinking skills**, those that require mental activity above the level of memorization or translation, are the elements which distinguish true learning from simple training. Often these higher order thinking skills are characterized as: interpretation, application, analysis, synthesis, and evaluation. The NC Standard Course of Study (p. 10) recognizes that students should be "*.....guided in their use of these skills in each subject area at each grade level and in their application to ' real life' situations.*" The science laboratory is the primary vehicle for confronting students with the "real life" nature of science. It is, therefore, one of the most productive tools for the encouragement and development of higher order thinking skills. Its presence in the curriculumn should be guarded and expanded.

These three elements,

- **hands-on experience with science**,
- **acquisition of science process skills**, and
- **practice with higher order thinking skills**

are more effectively emphasized through laboratory experiences than any other method of science instruction. Therefore, it is the laboratory which must become the primary focus of instruction for the science teacher who wants to integrate concepts with processes, and portray science as more than the acquisition of isolated facts and endless vocabulary.

As an aid to the effective use of experiments in chemistry instruction, the experiments found in four of the most frequently used texts have been arranged according to the recommended topical outline of the NC Curriculum. They are found in an annotated list which follows.

III. Chemistry Lab Outline

Experiments in popular texts are arranged according to the learning objectives of the North Carolina Competency Based Curriculum. The texts included are:

Wagner, (**W**) - Wagner, Maxine. Laboratory Manual for Chemistry, Cebco Standard Publishing, Fairfield, NJ 1983.

Metcalf, (**M**) - Metcalf,H.C., Williams, J.E., and Caska, J.F. Laboratory Experiments in Modern Chemistry, Holt, Rinehart and Winston, New York, NY 1982.

Silver Burdett, (**SB**) - Ferguson, H.W., Schmuckler, J.S., Caro, A.N., and Johnson, A. Laboratory Investigations in Chemistry, Silver Burdett Company, Morristown, NJ 1978.

Smoot, (**SM**) - Carmichael, L.N., Haines, D.F., and Smoot, R.C. Laboratory Chemistry, Charles E. Merrill Publishing Company, Columbus, OH 1983.

The experiments included in this list were selected on the bases of their appropriateness to the curriculum, their apparent safety, and their utility as representative examples of current textbook material. In many cases, brief suggestions for making the experiment safer or avoiding unnecessary hazardous waste are included.

No chemical procedure can be guaranteed "safe". All experiments recommended in this manual appear to present minimum hazards. However, there is no guarantee, expressed or implied, that an experiment or procedure will not cause injury. Each teacher selecting an experiment should try it out under carefully controlled conditions before using it as a class exercise. Any necessary safety precautions should be added to the material given to the students. Activities which cannot be deemed safe for students should be altered in their delivery mode, have additional safety factors added or deleted totally.

For any laboratory experiment or chemical demonstration, "forseeable" hazards must be anticipated, safety equipment tested and immediately available, and emergency simulations practiced with the students.

Approved Safety Glasses should be worn whenever any potential for eye injury exists. The glasses should be of a type specified by the American National Safety Institute (**ANSI** Z87.1).

Letters following each experiment title [(W), (M), (SB), (SM)] refer to the four texts mentioned on the previous page. The associated numbers refer to the experiment number in the text. A bold Greek mu (μ) means that experiment could easily be converted to micro-scale.

1. Introduction to the Science of Chemistry

1.1 Methods and processes of science

Qualitative Observations 1 (W)
Quantitative Observations 2 (W)
Measuring Mass 3 (W)
Laboratory Procedures 1 (M); 1 (SB)
(Omit glass bending - Risk exceeds benefit!)
Scientific Method 1 (SM)

1.2 Properties of matter and energy

Density Determination 4 (W)

1.3 Conservation of matter and energy

Conservation of Mass 2 (SM)
(Lead and Chromate compounds generate hazardous waste that must be stored and disposed properly. This lab is recommended only if these compounds are used in significantly reduced quantities or if suitable substitute compounds are used.)
Mole Relationship in a Chemical Reaction 10 (SM) μ
Conservation of Matter 13 (W)

2. Matter—Classification and Changes

2.1 Classification of matter

2.2 Atoms and molecules

Approximating Molecular Size 11 (SB)
(Chalk dust may be used as a substitute for Lycopodium powder)

2.3 Elements, compounds, and mixtures

Chromatography 23 (SM)
(Omit Section C to avoid generating hazardous waste from heavy metals and chromates.)
Chromatography 4 (SB)
KOOL AID™ Chromatography (see later in this book) is an environmentally sound experiment that provides good quantitative data.

2.4 Nuclear changes

2.5 Physical changes

Chemical and Physical Changes in Matter 4 (SM) µ
(Observe caution for proper ventilation in Part 4; use of a fume hood is recommended. Only a very small quantity of copper (II) nitrate should be used. Part 5a uses barium and chromate salts. This part should be done with drop quantities to avoid unnecessary quantities of hazardous waste and unnecessary student exposure to these highly toxic materials.)
Allotropic Forms of Sulfur 25 (SM)
(Highly toxic gases such as hydrogen sulfide are produced in this experiment. The presence of these gases in a high school laboratory is not recommended.)
Physical and Chemical Changes 5 (W)
Allotropes of Sulfur 20 (W)
(Carbon disulfide, an extremely flammable substance and a known carcinogen is used as a solvent in this experiment. This experiment is therefore not recommended.)
Energy and Entropy: Phase Changes 3 (M)
(Acetamide is a suspected carcinogen, and should not be used. Mini-scaling with p-Dichlorobenzene is a possible alternative.)
Freezing Point Depression of a Solvent 14 (M) µ
(Same comment about Acetamide as above.)
Carbon 19 (M) µ

2.6 Chemical changes

Chemical and Physical Changes in Matter 4 (SM) µ
(see 2.5)

Observation and Experiment 1 (SB)
Physical and Chemical Changes 5 (W)

3. Descriptive Chemistry and Periodic Properties of Elements

3.1 Atomic models and electronic configurations

Flame Tests 5 (M), 13 (SM), 14 (W)

Suggested Procedure for Flame Test Lab

Using only suggested salts which are appropriate for use in high school chemistry labs, prepare about 50 mL of a 0.1 M solution for each salt. These solutions should then be placed in small beakers or wide mouth bottles. Soak wooden splints in the solutions overnight. Students then use tweezers to hold the splint in the Bunsen flame. As the splint burns at the end, it can be cut shorter and reused. Prepare only one set of solutions and let the students rotate from station to station. [Some splints contain excessive amounts of sodium which can blanket the other flame colors. This can be partially remedied by soaking the splints in distilled water for several days and air drying before use.]

After use, the remaining solutions can be flushed down the drain with excess running water. Unused splints may be sent to the sanitary landfill.

Energies of Electrons 15 (SM)
Energy Relationships of Metallic Ions 20 (SM)
(Eliminate Mercury!)
Emission Spectra 15 (W)

3.2 Periodic properties and the periodic table of elements

Qualitative Analysis 18 (SM)
Activity of Groups IA, IIA, VIIA 19 (SM)
(Eliminate metallic Potassium from part C)
Group 2A Metals 18 (W) μ
(Reduce volumes in Part 4 from mL to drops. Complete operation on a spot plate or in very small test tubes.)
Group 7A: Halogens 19 (W)
(Eliminate Part 2 since the use of Carbon tetrachloride is not appropriate in HS labs. Some teachers have successfully replaced CCl_4 with Mineral Oil.)

Tests for Iron (II) and Iron (III) Ions 6 (M) μ
(Reduce volumes from mL to drops.)
Oxidation States of Transition Metals 27 (M) μ
(Due to the presence of Chromium and Chromate ions, reduce volumes to drops.)
Halide Ions 29 (M)

4. Measurement and Computation

4.1 Use of tools and instrumentation

Spectrometer 14 (SM)
Solution Concentration using a Spectrometer 33 (SM)
Accuracy and Precision in Measurements 2 (M)

4.2 Scientific notation

4.3 Units and conversions
Density 3 (SM)
Mass/Volume Relations of Liquids and Solids 3 (SB)
(Do not use Trichloroethane.)
Density Determination 4 (W)

5. Stoichiometry and Kinetic Molecular Theory

5.1 Formulas and Equations

Empirical Formula 6 (SM) μ
(Due to the production of NO_2, this lab should be eliminated. It makes a good demonstration.)
Hydrated Crystals 7 (SM) μ
Chemical Changes and Equations 6 (SM) μ
(Students should not bend glass. In Part D, reduce mL to drops.)
A Partial Weight Analysis of a Compound 5 (SB) μ
(Substitute $MgSO_4 \cdot 7H_2O$ for copper sulfate.)
Composition of Hydrates 12 (W) μ
(Same substitution as above.)
Types of Chemical Reactions 23 (W) μ
(Omit mercury, and in Section D, reduce to drops.)
Empirical Formula 25 (W)

Water of Crystallization and Empirical
Formula of a Hydrate 7 (M)

5.2 Mole Concept

Empirical Formula 6 (SM) μ
Mole Relationship in a Chemical Reaction 10 (SM) μ
The Mole and Molar Volume 12 (SB)
Determining Gram Atomic Mass 24 (W)
Empirical Formula 25 (W)
Mole and Mass Relationship 27 (W) μ
Mass and Mole Relations in a Chem. Reaction 8 (M)

5.3 Stoichiometry

Quantitative Study of a Reaction 9 (SM) μ
(To save money, substitute other chemicals for Cu and $AgNO_3$, such as $CuCl_2$ and Al; or, CuCl and Al.)
Mole Ratios and Chemical Reactions 14 (SB) μ
(Substitutions should be made to eliminate Lead compounds.)
Reactions of Solutions 18 (SB)
(Substitute another compound for Lead Nitrate)
Relating Moles (Coefficients) 26 (W)
Mass-Mass Relationship 28 (W)
(It is strongly suggested that a substitute for Lead Nitrate be found. Students should not handle solid Lead Nitrate. Lead Iodide must be stored and disposed properly.)
Mass-Volume Relationship 30 (W) μ
Molecular Mass of a Gas 31 (W)

5.4 Behavior of Gases

Charles' Law 27 (SM)
(Students should not bend glass. Flexible plastic tubing can be set-up more quickly and safely and reused as well.)
Diffusion of Gases 28 (SM)
Molar Relations Involving Mass & Volume 29 (SM) μ
The Masses of Equal Volumes of Gases 6 (SB)
The Relationship Between Pressure and Volume 7 (SB)
The Pressure-Volume Relationship of a Confined Gas 8 (SB)
(Teacher demonstration only.)

Pressure vs. the Amount of Gas 9 (SB)
(Teacher demonstration only since uses mercury. CAUTION! Good chance of a mercury spill! Keep plastic dish pan under mercury to catch any spill.)
Temperature-Volume Relationship of a Gas 10 (SB)
(Teacher demonstration only. Student handling of mercury should be discouraged except under the closest of supervision. see above)
Boyles' Law 9 (W)
(Teacher demonstration only.)
Charles' Law 10 (W)
(Teacher demonstration only.)
Graham's Law 11 (W)
Hydrogen 22 (W)
(Teacher demonstration only.)
Molar Volume 29 (W) μ
Boyle's Law 9 (M)
Comparing Masses of Equal Volumes of Gases 10 (M)
(Not recommended.)
Molar Volume of a Gas 11 (M) μ

6. Chemical Reactions, Kinetics, and Thermodynamics

6.1 Oxidation-reduction

Oxidation-Reduction Reactions 44 (SM) μ
(Omit Section 4.)
Redox Reactions 44 (W) μ
(Treat lead salts appropriately. Omit Part 2.)
Oxidation-Reduction Titration 28 (SB)
(Treat waste appropriately!)
An Introduction to Redox and Ox. Potentials 29 (SB)
(Good demonstration.)
Oxidation-Reduction Reactions 25 (M)
(Treat waste appropriately!)
Redox Titration 44 (SM) μ

6.2 Electrochemistry

Electrochemical Cells 45 (SM) μ
(Teacher demonstration only.)
Corrosion 46 (SM)
Electrolysis 45 (W)

(Teacher demonstration only.)
Electrochemical Cells 46 (W)
(Teacher demonstration only. Appropriate disposal required!)
Corrosion of Iron 47 (W)
Oxidation Reduction Reactions 25 (M)

6.3 Energy effects

Energy and Enthalpy 31 (SM) μ
(Reduce the amount of p-Dichlorobenzene used! Could also be a demonstration with students taking data and discussing it afterward)
Heat of Fusio Sublimation 26 (SM) μ
(Reduce the amount of p-Dichlorobenzene used!)
Specific Heat of a Metal 11 (SM)
Heat of a Chemical Reaction 12 (SM)
Heat of Fusion of Ice 6 (W)
Calorimetry 7 (W)
Heating and Cooling Curves 8 (W) μ
Heats of Reaction 36 (W)
Heat Absorption and Heat Capacity 15 (SB)
Heat of Crystallization 12 (M)
Heat of Combustion 20 (M)
Heats of Reaction 21 (M)

6.4 Reaction rates

Reaction Rates 35 (SM)
Rates of Reactions 35 (W)
The Iodine Clock Reaction 21 (SB)
Rate of a Chemical Reaction 22 (M)

6.5 Equilibrium

Chemical Equilibrium 36 (SM)
(Reduce concentrations. Be prepared to handle the hazardous waste generated.)
Chemical Equilibrium 37 (W)
(Not recommended! Too many hazardous materials.)
Determination of Equilibrium Constant 22 (SB)
Equilibrium Expression SE-2 (M)
(Impractical!)

7. Electrolyte Solutions—Acids, Bases, and Salts

7.1 Importance

7.2 Naming

7.3 Characteristics and the Solution Process

Conductivity and Chemical Bonding 21 (SM)
(Avoid Mercury compounds!)
Bonds,Polarity, and Solubility 32 (W)
(Omit. Too many hazardous solvents.)
Properties of Acids and Bases 39 (W)
Solubility and Rate of Solution 13 (M)
Reacting Ionic Species in aqueous Solutions 15 (M)
(Prudent waste disposal required.)

7.4 Systems of concentration

Molecular Mass Determination
Using BP elev and FP dep 34 (SM)
Determination of Molecular Weight
by FP dep 16 (SB)
(Not recommended - hazardous materials!)
Percentage of acetic acid in vinegar 18 (M)

7.5 Ionization

Ionic Reactions 37 (SM)
Conductivity, Ionization, and Dissociation 40 (W)
(Useful as a Teacher's demonstration.)

7.6 Acid-base equilibria and pH

Hydronium Ion 40 (SM)
Hydrolysis 41 (SM)
Acid-Base Titration 42 (SM)
(Reduce quantities!)
Acid-Base Indicators 23 (SB)
Acid-Base Titration 24 (SB)
(Reduce quantities. Omit Part B.)
Hydrogen Ion Concentration 41 (W)
Acid-Base Titration 42 (W) μ
Hydrolysis of a Salt 43 (W)
Hydronium Ion Concentration, pH 16 (M)
Titration of an Acid and a Base 17 (M) μ

Aluminum and its Compounds 28 (M)
(Anhydrous $AlCl_3$ should not be used without proper precautions. This lab is not recommended.)

7.7 Solubility

Effect of Temperature on Solubility 32 (SM) μ
Ions in Solution 38 (SM) μ
(Not recommended - hazardous materials.)
Solubility Product Constant 39 (SM) μ
(Omit experiment, or find a substitute for Lead II Chloride.)
The concentration of a $Ca(OH)_2$ solution 30 (SB)
Solubility of a Salt 33 (W) μ
Precipitates and Solubility Rules 34 (W)
(Hazardous materials produced. Prudent disposal required.)
Solubility Product Constant 38 (W)
Rate of a Chemical Reaction 22 (M)
Equilibrium 23 (M)
Relative Solubilities of the Group II Metals 26 (M)
(Exercise caution with concentrated NH_3)

8. Organic Chemistry

8.1 Carbon

Melting Point Determination 48 (W)
(Test tube oil bath can be very dangerous because of the hot oil used! Use special melting point apparatus if available.)

8.2 Hybridization and bonding

8.3 Hydrocarbons

8.4 Hydrocarbon substitution products

Prepartion of Organic Compounds 48 (SM) μ
Prepartion of Soap, ... (SM)
(Omit Parts B and C.)
Organic Synthesis 37 (SB)
(Omit Part C.)

Plastics 38 (SB)
(Avoid this experiment - extremely hazardous materials! Do as a demonstration.)
Esters (Demo) 49 (W)
Saponification 50 (W)

8.5 Living things

Biochemistry (SM) μ

9. Relevance and Current Topics in Chemistry

9.1 Current topics

Natural Radioactivity 47 (SM)
Radioactivity (Demo) 16 (W)
Determining half life (Demo) 17 (W)
Radioactivity 30 (M)
(Special equipment required.)

9.2 Career opportunities

Chemistry of Photography 20 (SB)
The Chemistry of Copper 31 (SB)
Clathrates 39 (SB)
Determining a Reaction Mechanism 40 (SB)

Other Labs

Oxygen (Demo) 21 (W)
(Not recommended due to possibility of explosion!)

IV. Inventory

General Comments

A comprehensive chemical management system is an essential element of any science program, and particularly of a high school chemistry program. With increased federal, state and local regulations and ever more frequent litigation, the need for such management systems becomes ever more obvious.

The foundation of a management system is an accurate, complete and up-to-date inventory. At present, such an inventory is not specifically required by the North Carolina Department of Public Instruction but it may be required by the Department of Labor under the "Right to Know" standard or the "Hazard Communication Standard". However, since a chemical inventory is an important part of "generally accepted good laboratory practice", it will help to reduce chemical accidents and would assist the defense in case of litigation involving the use of chemicals in the school. For these reasons, it is wise to compile and maintain an accurate, complete and up-to-date chemical inventory.

The specific advantages of a chemical inventory are economic, legal and educational. With an up-to-date inventory, chemical purchases can be made more easily and excessive quantities can be avoided. This saves time and money on the initial purchase and also on waste disposal. The cost of waste disposal of some chemicals greatly exceeds their initial purchase price.

From a legal standpoint, the teacher is in better control of the chemicals with an inventory. Few unknown and/or unusually hazardous materials will be stored if the complete chemical holdings are routinely inventoried. The absence of missing or stolen chemicals will be more easily detected with a regular inventory system. In a court proceeding, few things would be more embarrassing and more incriminating than a teacher admitting lack of knowledge of the chemicals on hand. With a well culled inventory, there is much less chance of a student encountering a severe chemical danger. Accidents involving chemicals can not be blamed on school chemicals if an inventory is available to show that such a chemical is not stocked in the school.

The inventory can also serve as an important educational process. The system of storage in which incompatible chemicals are kept apart is a strong lesson in chemical reactivity. The sight of a teacher carefully storing and checking chemicals conveys an important safety lesson to the students that would be difficult to teach in other ways. Chemicals are substances to be respected. When handled carefully, they present no unusual danger.

Features of a Good Inventory

Identification - The inventory list should clearly identify the school, the address and telephone number of the school and the name and home phone number of the teacher in charge.

Date - Each time the inventory is made or up-dated, the list should be re-dated to indicate it's currency.

Alphabetical listing - Storage of chemicals should always be by reactivity type (see below) not by simple alphabetical order! This is essential. In the case of breakage of containers, there will be less of a chance of a violent chemical reaction when nearby chemicals mix. However, within each reactivity type, chemicals should be listed alphabetically, using appropriate IUPAC names. Cross-listing in the inventory list by trade names and by common names is very helpful. A chemical formula cross listing would also be helpful.

Quantity - Close monitoring of quantities is essential to the success of the inventory. Over ordering is one of the major causes of overstocked laboratories.

Receipt Date and Expiration Date - The date of receipt allows some judgement about the current utility of the substance. This date should also be written on the chemical container. A few materials have very short safe lifetimes. For example, ethers may form peroxides and become explosive. Thus, when available the expiration date should also appear on the list and on the container.

Location - The room and shelf location of each substance is essential.

A **"SUGGESTED SHELF STORAGE PATTERN"** is shown below. It is essential that incompatible chemicals be isolated from each other. This is accomplished by dividing the chemicals according to "Reactivity Types" In a totally alphabeticel storage system, there is a high probability that two incompatible chemicals will be stored side by side. In the event of breakage, they could react violently with each other.

Suggested Shelf Storage Arrangement*

INORGANIC #10
Sulfur, Phosphorous, Arsenic, Phosphorous Pentoxide

INORGANIC #2
Halides, Sulfates, Sulfites, Thiosulfates, Phosphates, *etc.*

INORGANIC #3
Amides, Nitrates, (**NOT** Ammonium Nitrate!)

INORGANIC #1
Metals & Hydrides
(Store away from any water!)

INORGANIC #4
Hydroxides, Oxides, Silicates, *etc.*

INORGANIC #7
Arsenates, Cyanides, etc.
(Store above acids)

INORGANIC #5
Sulfides, Selenides, Phosphides, Carbides, Nitrides, *etc.*
(Store away from any water!)

INORGANIC #8
Borates, Chromates, Manganates, Permanganates, *etc.*

INORGANIC #6
Chlorates, Perchlorates, Chlorites, Perchloric Acid, Peroxides, *etc.*

INORGANIC #9
Acids, except Nitric Acid
(Acids are best stored in dedicated cabinets)

ORGANIC #2
Alcohols, Glycols, *etc.*
(Store Flammables in a special cabinet)

ORGANIC #3
Hydrocarbons, Esters, *etc.*
(Store Flammables in a special cabinet)

ORGANIC #4
Ethers, Ketones, *etc.*
(Store Flammables in a special cabinet)

ORGANIC #5
Epoxy compounds, Isocyanates

ORGANIC #7
Sulfides, Polysulfides, *etc.*

ORGANIC #8
Phenols, Cresols

ORGANIC #6
Peroxides, Azides, *etc.*

ORGANIC #1
Acids,Anhydrides, Peracids, *etc.*

MISCELLANEOUS

MISCELLANEOUS
Nitric Acid

* see Flinn Scientific Catalog (listed in Bibliography at end) for additional details

Once the inventory has been completed and the chemicals have been arranged according to the suggested shelf storage plan, the storage area must be secured Only those few individuals with a genuine need for access should be given a key to the area.

The inventory list should be available in the storage area. The chemistry teacher(s), principal, and school safety officer or administrative officer should each have copies.

The typical high school might possess about 500 different chemicals according to a recent study conducted by the Science Division of the North Carolina Department of Public Instruction. Therefore, to adequately manage such a number of different substances a computer system is usually required.

Available Programs

At least two APPLE II or IBM PC based chemical Inventory systems are currently available. They are "The Total Science Safety System for Grades 7-14", and, "The Flinn Chemventory System".

"The Total Science Safety System for Grades 7-14" is a software system on Safety which contains an inventory program as part of the package. The program also contains a wide variety of safety related forms and a check-list for evaluating a science program. The Inventory program contains 423 chemicals commonly used in the high school chemistry laboratory. Each chemical entry includes current safety information, such as chemical synonyms, storage category, hazard classification, and NFPA (National Fire Protection Association) ratings. The storage location, including room number and shelf location, quantity, and expiration date can be designated for each substance on the list. Other substances can be added to the list and the safety data can be edited as new information becomes available. The program can be obtained in APPLE II or IBM format from NASCO or from Lab Safety Supply Company.

"The Flinn Chemventory System", available from Flinn Scientific Inc., is an Inventory system containing data on some 952 chemical and biochemical substances. Each entry contains substance name, grade (Reagent, USP, Technical, *etc.*), chemical class, compatible chemical families, hazardous character (if any) and suggested disposal method. It is available in versions for the APPLE II, IBM PC, or Radio Shack computers.

V. Information on Some Chemicals Used in Schools

LISTS OF RESTRICTED CHEMICALS

Numerous state and national organizations have published lists of chemicals that are "not recommended for use" or "are recommended for restricted use" in their science programs. These lists have caused much confusion and concern. The North Carolina "STOP" safety manual, "Safety First in Science Teaching, 1983" pp.25-28, contains such lists. These lists are by no means all inclusive or absolute. As new safety data and public awareness on the dangers of specific chemicals become available, such lists will continue to evolve.

The rationale for the North Carolina lists was based on available safety data and recommendations by an ad hoc Chemical Safety Committee. These recommendations were made in a sincere effort to safeguard the health of teachers and students and to protect the environment. It was recognized that little knowledge existed on the diversity and quantities of chemicals used or stored on the elementary, middle, and senior high schools.

The **"STOP"** Manual was circulated to all schools within North Carolina since it was possible that any school might contain any or all of the chemicals discussed. However, many misinterpretations of these lists have occurred. Many schools have gone to the needless expense of having all substances on the lists removed from the premises without considering whether the use of such substances could be adequately justified. For example, the substances listed might be difficult to justify for use by an elementary teacher with little or no science background. Likewise, many middle grade science teachers work in inadequate laboratory settings with poor or improper safety equipment. Use of hazardous substances under these conditions might be difficult to justify. However, at the high school level, a qualified chemistry teacher who works in a well equipped laboratory with appropriate safety equipment could easily justify, and indeed would require, the use of many chemicals on these lists. The 1988 revision of the **"STOP"** Manual no longer includes the lists!

JUSTIFICATION FOR USE OF CHEMICALS

Justification for using hazardous substances should also be based on how it is to be used. There are many different levels of use of and of exposure to, hazardous substances. For example, mercury is cited on the North Carolina list as "not for school use". The element is a cumulative poison and should not be handled or spilled. Its use at the elementary or middle school level may be questionable. However, the

benefits far outweigh the risks when it is used as an exhibition sample in a high school chemistry class. There might also be demonstrations or experiments in which a well qualified chemistry teacher could justify its use.

The current philosophy of chemical use is to minimize exposure by reducing the amounts used, reducing the concentrations used and, substituting less hazardous materials wherever practical. By "Micro-Scaling" an experiment, the quantities of chemicals used can usually be reduced by a factor of about 100 or more with no loss of pedagogical value but with a tremendous decrease in danger.

Some chemicals on these lists have been reported in elementary and middle schools where their risks often outweigh the potential benefits. However, prudent use of most of the listed chemicals has been recognized as essential to a complete high school chemistry laboratory program.

TEACHER RESPONSIBILITY

Each chemistry teacher must carefully evaluate each experiment to be sure that

- there is a reasonable justification for the use of the chemicals,
- the potential risks are understood,
- less hazardous substitutes are not available,
- the quantities to be used are as small as practical, and
- the problems of waste disposal are within the capabilities of the teacher and the school.

To make these decisions, the teacher must have adequate up-to-date safety training and be continually vigilant for new findings on the toxicity of chemicals.

PROPER PERSPECTIVE

A proper perspective on the use of hazardous substances is also essential. Life itself is not without risks. Most of us are exposed to hazardous substances and situations in our everyday environment and show little concern. At the same time, many of the same substances are being banned from the chemistry laboratory. For example, gasoline is highly flammable. It contains benzene, a known carcinogen, as well as other hydrocarbons and additives. Benzene is not recommended for school use, yet we fill our tanks with 10-15 gallons of gas and drive around with it in our tanks and think little about it.

A carefully selected group of active and experienced North Carolina teachers certified in chemistry, in conjunction with university level chemistry instructors, has researched the compounds on the 1983 **STOP** lists. The new annotated list is given on the following pages. It is provided for information only. It is <u>not</u> intended to be used as a list of particularly hazardous substances! It is offered <u>only</u> to clarify the 1983 **STOP** lists.

OMISSIONS

On preparing the following annotated version of the original list, several entries were omitted because the names given in the original list were not specific. These include Chlorobenzidines, Dichlorobenzene, Dichlorophenol, Gun Powder, Methylene bis(2-chloroaniline), Nitrosamines, and Pesticides. Polybrominated biphenyls (PBBs), Polychlorinated biphenyls (PCBs), and Polychlorodibenzofurans were also omitted since they are poorly defined mixtures of carcinogenic compounds which have no experimental use in the high school lab.

GLOSSARY

AHW - (Acute Hazardous Waste) - those discarded commercial chemical products listed in 40CFR 261.22 (e).

CANCER SUSPECT AGENT - A material for which there is some evidence (usually animal test results) that suggests the material may cause cancer in humans. This is not a widely accepted term.

CARCINOGEN - A material that has been found to cause cancer in humans or to cause cancer in animals and therefore considered capable of causing cancer in humans. A material may be designated as a carcinogen if (1) it has been evaluated by the International Agency for Research on Cancer (IARC) and found to be a carcinogen or potential carcinogen; (2) it is listed as a carcinogen or a potential carcinogen in the latest edition of the *Annual Report on Carcinogens*, published by the National Toxicology Program (NTP); (3) it is regulated by OSHA as a carcinogen; or (4) if one positive study has been published.

CAS Number - **C**hemical **A**bstracts **S**ervice registration number. This is an unambiguous, assigned designation for a material. Each chemical substances will have a unique CAS number. The CAS number has no chemical significance. It is often used in Government regulations and in literature searching, and is useful in avoiding confusion over synonyms, spelling or nomenclature. [Chemical Abstracts Service, Box 3012, Columbus, OH 43210 (614) 421-3600]

CERCLA - (Comprehensive Environmental Response, Compensation, and Liability Act) 1980 legislation that makes the persons responsible for the release of a hazardous substance liable for its cleanup.

CFR - Code of Federal Regulations

CORROSIVE - A chemical that causes visible destruction of, or irreversible alterations in living tissue by chemical action at the site of contact; a liquid that causes a severe corrosion rate in steel. A solid or liquid waste that exhibits a "characteristic" of corrosivity as defined in RCRA [40 CFR 261.22] may be regulated by EPA (U. S. Environmental Protection Agency) as a hazardous waste.

EPA - U. S. Environmental Protection Agency

EXPLOSIVE - A material that produces a sudden, almost instantaneous release of pressure, gas and heat when subjected to abrupt shock, pressure or high temperature.

FIRE HAZARD - A flammable or combustible material.

FLAMMABLE - A material with a Flash Point below 100° F (38° C).

FLASH POINT - The lowest temperature at which a liquid gives off sufficient vapor to form an ignitable mixture with air near its surface or within a vessel.

HAZARD COMMUNICATION STANDARD - 1983 OSHA regulations requiring proper training of employees and giving them the "Right to Know" the hazards of the materials with which they are working.

HAZARDOUS WASTE - An evolving term (40 CFR 261) used by EPA to determine what materials are subject to Hazardous Waste Regulations. In general, a material is deemed a hazardous waste if it meets any one of the characteristicsof Ignitability, Corrosivity, Reactivity or Toxicity as defined by EPA, or is "listed" as a hazardous waste. More than 400 substances are specifically "listed". Many more substances are "hazardous" waste by virtue of their "characteristics".

HIGHLY TOXIC - A material which has, (1) an LD_{50} of 50 mg/kg or less when administered to albino rats weighing 200 - 300 g each; (2) an LD_{50} of 200 mg/kg or less when administered by continuous contact for 24 hours with the bare skin of albino rabbits weighing 2-3 kg; or (3) an LC_{50} in air of 200 ppm or less (gas or vapor) or 2 mg/L or less (mist, fume, or dust) when administered by continuous inhalation for 1 hour to albino rats weighing 200 - 300 g each.

IRRITANT - A material that causes a reversible inflammatory effect on living tissue by chemical action at the site of contact as a function of concentration or duration of exposure.

LD_{50} - the dose (usually in mg/kg of body weight) which results in mortality of 50% of the test subjects.

MSDS - (Material Safety Data Sheet) Technical information sheets (usually 2-7 pages) provided by the manufacturer and describing the toxicity, physical hazards and methods of safe handling of a chemical substance. (see chapter VII)

NARCOTIC - A material that in moderate doses dulls the senses, relieves pain, and induces profound sleep, but which in excessive doses causes stupor, coma or convulsions.

NFPA Hazard Rating - A scale from 0-4 (4 represents the greatest hazard) assigned by the National Fire Protection Association (**NFPA**) to give quick information about a substance's Reactivity, Flammability, and Toxicity under emergency conditions. The ratings are not meant to identify the nonemergency health hazards of chemicals, but they are one of the few quantified listings of the relative hazards posed by various materials. These ratings are available for only a limited number of compounds. They are listed in two documents; NFPA 49 "Hazardous Chemical Data", and NFPA 325M "Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids" available from NFPA, Batterymarch Park, Quincy, MA 02269 1-800 344-3555. (See also, FLINN Catalog)

OSHA - Occupational Safety and Health Administration

OXIDIZER - A substance that yields oxygen readily to stimulate the combustion of organic matter. Examples include inorganic nitrates, perchlorates, permanganates, chromates and hypochlorites, concentrated inorganic and organic peroxides, chromium trioxide.

POISON - Class A - A DOT (Department of Transportation) term for extremely dangerous substances which when mixed in air in very small quantity are known to be dangerous to life. Examples include phosgene and hydrocyanic acid.

POISON - Class B - A DOT term for liquid, solid, paste, or semisolid substances other than Class A poisons or irritating materials that are known or presumed on the basis of animal tests to be so toxic to man as to afford a hazard to health during transportation.

RADIOACTIVE - A material that naturally emits alpha particles, or beta or gamma rays from spontaneous disintegration of its nuclei.

RCRA (Resource Conservation and Recovery Act) - Landmark legislation first appproved in 1976 which provided a "cradle to grave" system for the management of hazardous wastes from all sources.

REACTIVE - A material that is explosive, unstable, reacts with water violently, or forms explosive mixtures or generates dangerous quantities of toxic gases, such as hydrogen sulfide or hydrogen cyanide, with water at any pH.

RIGHT TO KNOW - NC law (G.S. 95-173 *et seq.*) which requires that appropriate information on hazardous materials be provided to fire fighters and to the community by users of hazardous materials.

SARA - (Superfund Amendments Reauthorization Act) - 1986 law which provides (among other

things) chemical emergency planning requirements and community rights to know requirements.

SUPERFUND - created by CERCLA in 1980 which pays for cleanup of abandoned hazardous waste sites.

SUSPECT CARCINOGEN - similar to Cancer Suspect Agent

TLV - TWA - Threshold Limit Value - Time Weighted Average

- The time weighted average concentration of an airborne substance for a normal 8 hr workday and a 40 hr work week to which nearly all workers may be repeatedly exposed, day after day, without adverse effect. These values have been developed by the ACGIH (American Conference of Governmental Industrial Hygienists), 6500 Glenway Avenue, Cincinnati, OH 45211, (513) 661-7881

TLV - STEL - Threshold Limit Value -Short Term Exposure Limit

- The maximum concentration of an airborne contaminant for a continuous exposure period of 15 minutes with a maximum of four such periods per day, with at least 60 minutes between such exposures, and provided that the **TLV-TWA** is not exceeded. Also developed by ACGIH

a - Parts of vapor or gas per million parts of contaminated air by volume at 25°C and 760 Torr

b - Approximate number of milligrams of substance per cubic meter of air

C denotes a ceiling value

Capital Letters **A**, **B**, **D**, and **E** refer to Appendices in the book of TLV values published by the ACGIH

Appendix **A**	- Carcinogens
Appendix **A**1a	- Human Carcinogens
Appendix **A**1b	- Human Carcinogens
Appendix **A**2	- Industrial Substances Suspect of Carcinogenic Potential for Man
Appendix **C**	- TLV's for Mixtures
Appendix **E**	- Simple Asphyxiants

TOSCA - (Toxic Substance Control Act) - landmark legislation passed in 1976 permitting EPA to ban the manufacture, processing, distribution and use of "toxic" materials.

TOXIC - A material which has, (1) an LD_{50} of 50 to 500 mg/kg when administered orally to albino rats weighing 200 - 300 g each; (2) an LD_{50} of 200 to 1,000 mg/kg when administered by continuous contact for 24 hours with the bare skin of albino rabbits weighing 2-3 kg; or (3) an LC_{50} in air of 200 to 2000 ppm (gas or vapor) or 2 to 20 mg/L (mist, fume, or dust) when administered by continuous inhalation for 1 hour to albino rats weighing 200 - 300 g each.

Chemical List

Compound Name	CAS Number	NFPA Hazard Ratings Health Flammability Reactivity	Comments/TLV ppm[a] mg/m³ [b]
Acetamide	[60-35-5]		SUSPECT CARCINOGEN
Acetylaminofluorene			KNOWN CARCINOGEN
Acetylene	[74-86-2]	1 4 3	EXTREMELY FLAMMABLE (compressed gas) E -
Acid Green	[4680-78-8]		
Acrylonitrile	[107-13-1]	4 3 2	KNOWN CARCINOGEN 2, A2 4.5, A2
Aluminum chloride, anhydrous	[7446-70-0]	3 0 2	Severe respiratory irritant; reacts violently with water
Ammonium chromate (VI)	[7788-98-9]		Dust is a known carcinogen
Ammonium dichromate	[7789-09-5]	1 1 1	Fire hazard; dust is possibly carcinogenic
Ammonium metavanadate	[7803-55-6]		HIGHLY TOXIC; AHW #P119
Ammonium oxalate	[6009-70-7]		Toxic by ingestion and inhalation
Ammonium perchlorate	[7790-98-9]	2 0 4	Strong oxidant; SUSPECT CARCINOGEN
Aniline	[62-53-3]	3 2 0	SUSPECT CARCINOGEN 2 10
Aniline hydrochloride	[142-04-1]		SUSPECT CARCINOGEN
Anthracene	[120-12-7]	0 1 -	
Antimony	[7440-36-0]		Fumes are toxic - 0.5
Antimony (III) oxide	[1309-64-4]		HIGHLY TOXIC - 0.5
Antimony potassium tartrate (Potassium antimonyl tartrate hemihydrate)	[28300-74-5]		Toxic by inhalation and ingestion

Compound Name	CAS Number	NFPA Hazard Ratings (Health / Flammability / Reactivity)	Comments/TLV ppm[a] mg/m³ [b]
Antimony (III) chloride	[10025-91-9]		HIGHLY CORROSIVE
Arsenic	[7440-38-2]		HIGHLY TOXIC - 0.2
Arsenic (III) chloride	[7784-34-1]	3 0 0	HIGHLY TOXIC
Arsenic (III) oxide	[1327-53-3]		HIGHLY TOXIC; AHW #P012 - A2
Arsenic (V) oxide	[1303-28-2]		HIGHLY TOXIC; AHW # P011
Asbestos - generic term for substances such as Anthophyllite Chrysotile Tremolite	 [17068-78-9] [12001-29-5] [14567-73-8]		KNOWN CARCINOGEN - A1a
Ascarite	[81133-20-2]		NaOH coated Asbestos
Auramine	[2465-27-2]		Biological Stain
Barium chloride	[10361-37-2]		Toxic by ingestion; 0.8 g may be fatal
Barium oxalate	[516-02-9]		Toxic by ingestion
Benzene	[71-43-2]	2 3 0	KNOWN CARCINOGEN 10,A2 30,A2
Benzidine	[92-87-5]		KNOWN CARCINOGEN - A16
Benzoyl peroxide	[94-36-0]	1 4 4	EXPLOSION SENSITIVE - 5
Beryllium carbonate	[13106-47-3]		HIGHLY TOXIC; SUSPECT CARCINOGEN
Bromine	[7726-95-6]	4 0 0	STRONG OXIDIZER; highly toxic by inhalation and ingestion; severe skin irritant 0.1 0.7
Cadmium , metal	[7440-43-9]		KNOWN CARCINOGEN - 0.05
Cadmium acetate	[89759-80-8]		KNOWN CARCINOGEN
Cadmium bromide	[7789-42-6]		SUSPECT CARCINOGEN

Compound Name	CAS Number	NFPA Hazard Ratings (Health / Flammability / Reactivity)	Comments/TLV ppm[a] mg/m³[b]
Cadmium carbonate	[513-78-0]		SUSPECT CARCINOGEN
Cadmium chloride	[10108-64-2]		KNOWN CARCINOGEN
Cadmium sulfate	[10124-36-4]		KNOWN CARCINOGEN
Calcium carbide	[75-20-7]	1 4 2	Flammable; acetylene produced when exposed to water or moisture
Calcium cyanide	[592-01-8]	3 0 0	HIGHLY TOXIC
Calcium fluoride	[7789-75-5]		TOXIC; Skin irritant
Carbon disulfide	[75-15-0]	2 3 0	CARCINOGENIC; AHW #P022 EXTREMELY FLAMMABLE 10 30
Carbon tetrachloride	[56-23-5]	3 0 0	KNOWN CARCINOGEN 5,A2 30,A2
Carmine	[1260-17-9]		Biological stain
Catechol	[120-80-9]		TOXIC; Irritant 5 20
Chloral hydrate	[302-17-0]		Hypnotic drug
Chloretone (1,1,1-Trichloro-2-methyl-2-propanol)	[6001-64-5]		Hypnotic drug
Chlorine	[7782-50-5]	3 0 0	Pungent, toxic gas 1 3
Chloroform	[67-66-3]	2 0 0	Toxic by inhalation; Mild carcinogen 10,A2 50,A2
bis-Chloromethyl ether	[542-88-1]		POTENT CARCINOGEN; AHW #P016 0.001,A1a 0.005
Chloroprene	[126-99-8]	2 3 0	HIGHLY TOXIC
Chromium	[7440-47-3]		Heavy metal; Dust is a CARCINOGEN - 0.5
Chromium (II) acetate	[4112-22-5]		Easily oxidized to Chromium (III) acetate - 0.5

Compound Name	CAS Number	NFPA Hazard Ratings (Health / Flammability / Reactivity)	Comments/TLV ppm[a] mg/m³[b]
Chromium (III) acetate	[1066-30-4]		- 0.5
Chromium (III) oxide	[1308-38-9]		- 0.5
Chromium (VI) oxide (Chromic acid) (Chromic anhydride)	[1333-82-0]		HIGHLY TOXIC; Powerful oxidizing agent; CORROSIVE to skin; Fume and dust are CARCINOGENIC - 0.5
Chromium (III) potassium sulfate	[7788-99-0]		Toxic by ingestion - 0.5
Cobalt	[7440-48-4]		- (0.1)
Cobalt (II) nitrate hexahydrate	[10026-22-9]	1 0 0	Oxidizer; Moderately toxic
Colchicine	[64-86-8]		HIGHLY TOXIC; gout remedy
Cyclohexane	[110-82-7]	1 3 0	FLAMMABLE; Toxic by inhalation and contact 300 1,050
Cyclohexene	[110-83-8]	1 3 0	FLAMMABLE; Toxic by inhalation 300 1,015
p-Dichlorobenzene	[106-46-7]	2 2 0	Severe irritant; Toxic by ingestion 75 450
1,2-Dichloroethane (Ethylene dichloride)	[107-06-2]	2 3 0	CARCINOGEN 10 40
Dichloroindophenol, sodium salt	[620-45-1]		Hygroscopic
Dichloromethane (Methylene chloride)	[75-09-2]	2 1 0	Narcotic in high conc'n. (100) (350)
Diethyl sulfate (Ethyl sulfate)	[64-67-5]	3 1 1	CARCINOGEN
4-Dimethylamino-azobenzene	[60-11-7]		CARCINOGEN

Compound Name	CAS Number	NFPA Hazard Ratings Health Flammability Reactivity	Comments/TLV ppm[a] mg/m³ [b]
Dimethylaniline	[121-69-7]	3 2 0	Insufficient name 5 25
Dimethyl sulfate	[77-78-1]	4 2 0	POTENT CARCINOGEN 0.1,A2 0.5,A2
2,4-Dinitrophenol	[51-28-5]		HIGHLY TOXIC; AHW #P048 Flammable
p-Dioxane	[123-91-1]	2 3 1	CARCINOGEN; Forms explosive peroxides on storage 25 90
Diphenylamine	[122-39-4]	3 1 0	CARCINOGEN - 10
Diphenyl carbonate	[102-09-0]		
Ethyl ether (Diethyl ether)	[60-29-7]	2 4 1	EXTREMELY FLAMMABLE 400 1,200
Ethylene dichloride (1,2-Dichloroethane)	[107-06-2]	2 3 0	CARCINOGEN 10 40
Ethylene imine	[151-56-4]	3 3 2	CARCINOGEN 0.5 1
Ethylene oxide	[75-21-8]	2 4 3	SUSPECT CARCINOGEN Explosive vapors 1,A2 2,A2
Formaldehyde solution (Formalin)	[50-00-0]	2 2 0	SUSPECT CARCINOGEN; Strong irritant 1,A2 1.5,A2
Fuchsin acid	[3244-88-0]		Plasma stain
Gasoline	[8006-61-9]	1 3 0	FLAMMABLE; Fumes are toxic; Contains benzene 300 900
Hematoxylin	[517-28-2]		Alleged CARCINOGEN

Compound Name	CAS Number	NFPA Hazard Ratings (Health / Flammability / Reactivity)	Comments/TLV ppm[a] mg/m³[b]
Hexachlorophene	[70-30-4]		CARCINOGEN
Hydrazine	[302-01-2]	3 3 2	Explosive vapors; Cancer suspect agent 0.1,A2 0.1,A2
Hydriodic acid	[10034-85-2]	3 0 0	CORROSIVE; Light sensitive
Hydrobromic acid	[10035-10-6]	3 0 0	CORROSIVE
Hydrofluoric acid	[7664-39-3]	4 0 0	HIGHLY TOXIC; CORROSIVE
Hydrogen	[1333-74-0]	0 4 0	HIGHLY FLAMMABLE; Compressed gas E -
Hydrogen cyanide	[74-90-8]	4 4 2	HIGHLY TOXIC; AHW #P063 C10 C10
Hydrogen sulfide	[7783-06-4]	3 4 0	EXTREMELY TOXIC; (Comparable to HCN) 10 14
Hydroquinone	[123-31-9]	2 1 0	CORROSIVE; Toxic by ingestion and inhalation - 2
Indigo carmine	[860-22-0]		Light sensitive
Isoamyl alcohol (3-Methyl-1-butanol)	[123-51-3]	1 2 0	Vapor is irritating 100 360
Isobutyl alcohol (2-Methyl-1-propanol)	[78-83-1]	1 3 0	Vapor is irritating 50 150
Lead (II) acetate	[301-04-2]		KNOWN CARCINOGEN
Lead arsenate	[10102-48-4]	2 0 0	HIGHLY TOXIC - 0.15
Lead (II) carbonate, basic	[598-63-0]		HIGHLY TOXIC
Lead (II) chloride	[7758-95-4]		Toxic by ingestion and inhalation
Lead (II) chromate	[7758-97-6]		HIGHLY TOXIC - 0.05,A2

Compound Name	CAS Number	NFPA Hazard Ratings Health Flammability Reactivity	Comments/TLV ppm[a] mg/m³[b]
Lead (II) nitrate	[10099-74-8]	1 0 0	STRONG OXIDANT; Toxic by ingestion and inhalation
Lithium, metal	[7439-93-2]	1 1 2	Reacts with water
Lithium chloride	[7447-41-8]		Hygroscopic
Lithium nitrate	[7790-69-4]		TOXIC
Magenta I (Basic Fuchsin)	[569-61-9]		CARCINOGEN
Magnesium, metal	[7439-95-4]	0 1 2	Combustible solid
Magnesium, powder	[7439-95-4]	0 1 2	FLAMMABLE SOLID; Moisture sensitive
Magnesium perchlorate	[10034-81-8]	1 0 0	OXIDIZER; EXPLOSIVE Irritant; Unstable
Mercury	[7439-97-6]		HIGHLY TOXIC .05
Mercury (I) chloride (Calomel) (Mercurous chloride)	[10112-91-1]		TOXIC
Mercury (II) chloride	[7487-94-7]		HIGHLY TOXIC
Mercury (I) nitrate, monohydrate (Mercurous nitrate)	[7782-86-7]		HIGHLY TOXIC
Mercury (II) nitrate, monohydrate	[7783-34-8]		HIGHLY TOXIC; Poor shelf life
Mercury (I) oxide	[15829-3-5]		HIGHLY TOXIC
Mercury (II) oxide	[21908-53-2]		HIGHLY TOXIC; Decomposes upon exposure to light
Mercury (II) sulfate	[7783-35-9]		HIGHLY TOXIC; Decomposes upon exposure to light
Mercury (II) sulfide	[1344-48-5]		HIGHLY TOXIC; Decomposes upon exposure to light

Compound Name	CAS Number	NFPA Hazard Ratings (Health / Flammability / Reactivity)	Comments/TLV ppm[a] mg/m³[b]
Mesitylene (1,3,5-trimethyl benzene)	[108-67-8]	0 2 0	FLAMMABLE
Methyl chloromethyl ether	[107-30-2]		CARCINOGEN
Methylene chloride (Dichloromethane)	[75-09-2]	2 1 0	Narcotic in high conc'n. (100) (350)
Methyl ethyl ketone (2-Butanone)	[78-93-3]	1 3 0	FLAMMABLE 200 590
Methyl iodide (Iodomethane)	[74-88-4]		CARCINOGEN 2,A2 10,A2
Methyl methacrylate	[80-62-6]	2 3 2	EXPLOSIVE 100 410
Methyl oleate	[112-62-9]		Mild irritant; Some salts are poisonous
Methyl Orange	[547-58-0]		pH indicator
Methyl Red	[493-52-7]		pH indicator
β-Naphthylamine (2-Aminonaphthalene) (2-Naphthylamine)	[91-59-8]		CARCINOGEN - A16
Nickel, metal	[7440-02-0]	2 4 0	Dust or powder is toxic - 1
Nickel (II) acetate tetrahydrate	[6018-89-9]		CARCINOGEN
Nickel ammonium sulfate (Ammonium nickel sulfate)	[15699-18-0]		CARCINOGEN
Nickel (II) carbonate hydrate	[3333-67-3]		CARCINOGEN
Nickel (II) chloride hexahydrate	[7791-20-0]		CARCINOGEN
Nickel (II) nitrate hexahydrate	[13478-00-7]	1 0 0	CARCINOGEN
Nickel (II) oxide	[1313-99-1]		CARCINOGEN
Nicotine	[54-11-5]	4 1 0	HIGHLY TOXIC; AHW #P075 - 0.5

Compound Name	CAS Number	NFPA Hazard Ratings Health Flammability Reactivity	Comments/TLV ppm[a] mg/m³[b]
4-Nitrobiphenyl	[92-93-3]	2 1 0	CARCINOGEN
Nitrocellulose (Cellulose nitrate)	[9004-70-0]	2 3 3	EXPLOSIVE
Nitrogen dioxide (Dinitrogen tetroxide) (Nitrogen peroxide)	[10102-44-0]	3 0 0	EXTREMELY TOXIC; AHW #P078 3 6
2-Nitronaphthalene	[581-89-5]	(1) (1) (0)	SUSPECT CARCINOGEN
N-Nitrosodimethylamine	[62-75-9]		CARCINOGEN; AHW #P082
4-Nitrosophenol	[104-91-6]		CARCINOGEN
Osmium tetroxide (Osmic acid)	[20816-12-0]		HIGHLY TOXIC; AHW #P087 0.0002 0.002
Oxygen	[7782-44-7]		Compressed gas
Paris Green	[12002-03-8]		HIGHLY TOXIC; Arsenic compound
Pentane	[109-66-0]	1 4 0	HIGHLY FLAMMABLE 600 1,800
Petroleum ether (Ligroine; mixture of hydrocarbons)	[8032-32-4]	1 4 0	HIGHLY FLAMMABLE
Phenol	[108-95-2]	3 2 0	HIGHLY TOXIC; CORROSIVE 5 19
Phenylthiocarbamide (Phenylthiourea)	[103-85-5]		HIGHLY TOXIC; AHW #P093 Decomposes to form sulfur and nitrogen oxide fumes
Phosphorus (V) oxide	[1314-56-3]		CORROSIVE; Moisture-sensitive
Phosphorus, red	[7723-14-0]	0 1 1	Flammable solid; Less reactive than white Phosphorus
Phosphorus, white	[7723-14-0]	3 3 1	Spontaneous combustion in air
Phthalic anhydride	[85-44-9]	2 1 0	1 6

Compound Name	CAS Number	NFPA Hazard Ratings Health / Flammability / Reactivity	Comments/TLV ppm[a] mg/m³[b]
Picric acid (2,4,6-Trinitrophenol)	[88-89-1]	2 4 4	EXPLOSIVE - 0.1
Potassium, metal	[7440-09-7]	3 1 2	HIGHLY REACTIVE; FLAMMABLE SOLID; Moisture-sensitive
Potassium chlorate	[3811-04-9]	2 0 0	STRONG OXIDIZER; Irritant; May explode when shocked or heated
Potassium chromate	[7789-00-6]		CARCINOGEN
Potassium cyanide	[151-50-8]	3 0 0	POISON; AHW #P098
Potassium oxalate monohydrate	[6487-48-5]		HYGROSCOPIC
Potassium periodate	[7790-21-8]		STRONG OXIDIZER; IRRITANT
Potassium permanganate	[7722-64-7]	1 0 0	POWERFUL OXIDIZING AGENT; Can explode on sudden heating;Strong skin irritant
Potassium sulfide	[1312-73-8]	2 1 0	Fire risk
1-Propanol (n-Propyl alcohol)	[71-23-8]	1 3 0	FLAMMABLE 200 500
β-Propiolactone	[57-57-8]	0 2 0	CARCINOGEN 0.5,A2 1.5,A2
Pyridine	[110-86-1]	2 3 0	FLAMMABLE LIQUID; IRRITANT 5 15
Pyrogallic acid (Pyrogallol)	[87-66-1]		Toxic irritant
Saccharin (o-Benzoic sulfimide)	[81-07-2]		SUSPECT CARCINOGEN of low potency
Salicylamide (2-Hydroxybenzamide)	[65-45-2]		Dangerous; Emits highly toxic fumes when heated to decomposition
Salol (Phenyl salicylate)	[118-55-8]		Toxic by ingestion

Compound Name	CAS Number	NFPA Hazard Ratings Health Flammability Reactivity	Comments/TLV ppm[a] mg/m³ [b]
Selenium	[7782-49-2]		- 0.2
Silver cyanide	[506-64-9]		HIGHLY TOXIC; AHW #P104
Silver nitrate	[7761-88-8]	1 0 0	HIGHLY TOXIC; Corrosive solid
Silver (II) oxide	[1301-96-8]		FLAMMABLE; EXPLOSIVE
Sodium, metal	[7440-23-5]	3 1 2	Reacts violently with water
Sodium arsenate, dibasic heptahydrate	[10048-95-0]		HIGHLY TOXIC
Sodium arsenite	[7784-46-5]		HIGHLY TOXIC
Sodium azide	[26628-22-8]		EXPLOSIVE; AHW #P105 C.1 C.3
Sodium bromate	[7789-38-0]		Powerful oxidizing agent; Toxic; Skin irritant
Sodium chlorate	[7775-09-9]	1 0 2	OXIDIZER; CORROSIVE
Sodium chromate tetrahydrate	[10034-82-9]		CANCER SUSPECT AGENT (as dust); OXIDIZER
Sodium cyanide	[143-33-9]	3 0 0	HIGHLY TOXIC; AHW #P106
Sodium dichromate (VI)	[10588-01-9]	1 0 1	HIGHLY TOXIC; OXIDIZER CANCER SUSPECT AGENT as dust
Sodium ferrocyanide	[13601-19-9]		
Sodium fluoride	[7681-49-4]	2 0 0	Toxic by ingestion and inhalation; Strong skin irritant
Sodium nitrate	[7631-99-4]	1 0 0	OXIDIZER; IRRITANT
Sodium nitrite	[7632-00-0]		OXIDIZER; TOXIC Produces nitrogen dioxide
Sodium oxalate	[62-76-0]		Toxic by ingestion; Poor shelf life

Compound Name	CAS Number	NFPA Hazard Ratings (Health / Flammability / Reactivity)	Comments/TLV ppm[a] mg/m³[b]
Sodium silicofluoride (Na_2SiF_6)	[16893-85-9]		May cause death or permanent injury after short exposure to small quantities
Sodium sulfide	[1313-82-2]	2 1 0	Flammable solid; CORROSIVE
Sodium thiocyanate	[540-72-7]		Toxic irritant
Stannic chloride (Tin (IV) chloride)	[7646-78-8]	3 0 1	TOXIC; CORROSIVE
Stearic acid	[57-11-4]	1 1 0	
Strontium, metal	[7440-24-6]		FLAMMABLE; EXPLOSIVE
Strontium nitrate	[10042-76-9]	1 0 0	
Sudan III	[85-86-9]		Biological stain
Sudan IV	[85-83-6]		SUSPECT CARCINOGEN
Sulfamethazine	[57-68-1]		Decomposes when heated; produces sulfur oxides
Sulfuric acid, fuming	[7664-93-9]	3 0 2	CORROSIVE - 1
Talc (Hydrous magnesium silicate)	[14807-96-6]		May contain asbestos
Tannic acid	[1401-55-4]	0 1 0	SUSPECT CARCINOGEN
1,1,2,2,-Tetrabromo - ethane (Acetylene tetrabromide)	[79-27-6]	3 0 1	SUSPECT CARCINOGEN 1 15
Thallium compounds	[7440-28-0]		HIGHLY TOXIC; AHW #P113-5 - 0.1
Thermit	[8049-32-9]		Fire hazard
Thioacetamide	[62-55-5]		CARCINOGEN
Thiourea	[62-56-6]		SUSPECT CARCINOGEN
Titanium trichloride	[7705-07-9]		Fire risk

Compound Name	CAS Number	NFPA Hazard Ratings (Health / Flammability / Reactivity)	Comments/TLV ppm[a] mg/m³[b]
Toluene	[108-88-3]	2 3 0	FLAMMABLE; Toxic by ingestion, inhalation and skin absorption 100 375
o-Toluidine	[95-53-4]	3 2 0	SUSPECT CARCINOGEN 2,A2 9,A2
Trichloroethylene	[79-01-6]	2 1 0	CANCER SUSPECT AGENT 50 270
1,1,2-Trichloro - trifluoroethane	[76-13-1]		Body tissue irritant
Uranium	[7440-61-1]		RADIOACTIVE; Heavy metal - 0.2
Uranyl acetate	[541-09-3]		HIGHLY TOXIC
Uranyl nitrate	[10102-06-4]	1 0 0	HIGHLY TOXIC; OXIDIZER
Urethane (Ethyl carbamate)	[51-79-6]		SUSPECT CARCINOGEN
Wood's metal	[76093-98-6]		Lead alloy; TOXIC
Xylenes, mixed	[1330-20-7]	2 3 0	FLAMMABLE LIQUID

VI. Treatment of Hazardous Waste

Disposal of hazardous materials is a serious concern of today's high school chemistry teacher. Commercial disposal is an effective, but very expensive, option that is always available. However, the often changing local, state and federal rules governing transportation and disposal must be consulted and obeyed. Only properly certified waste disposal contractors may be used. The National Academy of Sciences', "Prudent Practices for the Disposal of Chemicals from Laboratories," provides an excellent overview of the subject and provides many good alternatives to commercial disposal.

It is therefore very important that the high school chemistry teacher understand commercial hazardous waste disposal, and its alternatives.

Commercial

Historically, the majority of hazardous materials have been sent to land fills. Although the technology of making these sites 'secure' has greatly improved over the past ten years, there is always the concern that they will eventually leak and contaminate ground water and provide additional liability (financial and legal) to the disposer. EPA has tightened the regulations recently such that this mode of disposal will very quickly become prohibited for most wastes.

The increasingly preferred method of disposal is incineration. This method has the advantage of being relatively final. However, incineration requires very sophisticated equipment to guarantee that the solid or liquid waste is not converted to unacceptable air pollution. When halogenated wastes are incinerated, special scrubbers are required to remove the acidic vapors that are produced. To minimize disposal costs, halogenated wastes should be segregated from non-halogenated since the cost of incinerating the former is quite high.

No matter what the method of disposal may be, it may only be performed by a well qualified and EPA certified hazardous waste expert. Each waste is tracked by a paper trail from the time it is received by the shipper until it is incinerated or land filled. The generator remains responsible for any problems it may cause during and after the process of disposal.

Commercial transporters and/or hazardous waste disposal firms that have been of service to schools in the past include:

ECO-FLO
Box 10383
Greensboro, NC 27404
(919) 855-7925

Enviro-Chem Waste
Management Services
1005 Investment Ave.
Apex, NC 27502
(919) 362-9010

GSX Services
Rt. 1
Watlington Industrial Rd.
Reidsville, NC 27320
(919 342-6106

Before choosing one of these, or any commercial firm, be sure to insist on receiving a copy of their most recent EPA certification. Also, ask for references and consult them. Talk with the Hazardous Waste Specialist at the closest university, or with the North Carolina State Department of Natural Resources and Community Development (919) 733-7015; or, with the EPA Hazardous Waste Information Center 1-800-424-9346. The hiring of a waste disposal firm is a major decision which carries major extended legal and financial responsibilities and should be made only after careful deliberation and consultation with school administrators.

Chemical Exchanges

Another useful technique for reducing the size of a chemical inventory is to exchange among various users the excess inventory of each. These Chemical Exchanges can be very effective since one party receives a needed material at no cost while the other avoids the high cost of waste disposal. However, Department of Transportation (DOT) regulations must be followed for the packaging, labelling and transportation of the chemicals between institutions.

The essential ingredient to an effective exchange program is the availability of accurate chemical inventories. These lists are circulated regularly among the cooperating laboratories (*e.g.*, the schools in a given district). Before a new chemical is ordered, the inventories of the cooperating schools are consulted. If a needed chemical is found on one of the lists, a phone call can verify its availability. Delivery usually can be arranged in a matter of hours or days, instead of the weeks or months that many purchases require when they are processed through a bureaucratic system. Not only is this a savings of purchase costs, but also a great time saver. At least one waste exchange program is active in the state. Consult the Southeast Waste Exchange, The Urban Institute, University of North Carolina at Charlotte, UNCC Station, Charlotte, NC 28223 (704) 597-2307.

Amnesty Days

Very commonly, school laboratories have amassed a very large inventory of materials for which there is no reasonable expectation of use for several years. In this situation, it is best to arrange for EPA approved disposal. However, this can be extremely expensive. Also, many times the labels have disappeared and no one knows what might be contained in the bottle(s). Unless a material can be identified, it can not be accepted by the normal EPA approved processor.

To accommodate these common situations, some school systems have arranged an Amnesty Day. On such a day, any school in the district can dispose of any and all chemicals at little or no direct cost. Even the troublesome unknowns are often accepted on such special days. This is an excellent way to bring a high school lab into compliance and to reduce inventories to a level at which only supplies of chemicals that will be consumed in 1-2 years are retained.

Amnesty Days are usually arranged at the state level after lengthy negotiations with the US Environmental Protection Agency. They are never regularly scheduled events and therefore should not be the major focus of any hazardous materials disposal program. However, if an Amnesty Day has not been held in your area in several years, it would be a good idea to begin lobbying for one through your school administration and the local school board.

Between 1986-1988, the state of Iowa completed a state-wide chemical inventory, pick-up and disposal of all unwanted and/or hazardous materials from the school systems. For further information, consult the article by Gerlovich and Miller, "Removing Unwanted Chemicals from Schools: A Proven Plan" listed in the Bibliography.

Less is Better

Since hazardous waste disposal is a very expensive process that is complicated by extended legal responsibility, most generators have sought ways to minimize the amount of material that must be disposed. Using less is a sure way to accomplish this.

High school teachers should seek ways of significantly decreasing the quantities used in all experiments. Micro-Scale or Mini-Scale experiments usually have at least as much pedagogical impact as the more common Macro-Scale experiments. Moreover, they cost less for chemicals, they usually work faster, they expose the teacher and students to much lower concentrations of chemicals, and they provide greatly reduced quantities of materials to dispose. It is difficult to imagine why most schools have not already adopted this reduced scale experimentation.

In-House Treatment

There are many times that the wastes produced in the lab can and should be be treated "in house" by a knowledgeable chemistry teacher. When done correctly, this treatment reduces the risk of storage of hazardous waste and greatly reduces hazardous waste disposal costs. "Hazardous Chemicals: Information and Disposal Guide" by Armour, Browne and Weir contains practical suggestions for waste disposal and detoxification of a large number of common laboratory chemicals.

According to "Prudent Practices for Disposal of Chemicals from Laboratories" (produced by a "blue ribbon" panel of the National Research Council in 1983), many water soluble chemicals may be safely disposed in the sanitary sewer provided that the quantities are small and the chemicals are not unusually toxic. However, local sanitary sewer regulations vary widely and should be consulted for the compounds you need to dispose. The sewer should never be used if it flows directly into a system that enters the ground water directly such as a storm sewer or a septic tank system. Also, if the material is unusually volatile or has a strong odor, sewer disposal is not reasonable.

Many aqueous solutions may be safely disposed in the sewer if their pH is in the range of 6-10 and they do not contain any unusually toxic metals such as cadmium, chromium, lead, or mercury, or anions such as azide,cyanide or perchlorate. Often, a large volume of waste can be treated to concentrate the toxic material in the form of a precipitate. The remaining bulk of the solution can often be discarded down the drain. The precipitated toxics must be disposed as hazardous waste or recovered and reused.

In-house treatment is only feasible when the quantities of chemicals used in experiments or demonstrations are kept to a minimum. A Micro-Scale approach, combined with good ordering practices, will insure a small quantity of treatable waste. In turn, these low levels aid the teacher in practicing the art of chemical disposal.

Prudent purchasing procedures greatly decrease the costs of hazardous waste disposal. These include ordering a minimum quantity of chemicals, ideally only the amount used in one academic year. The volume discount that may be obtained by ordering larger quantities is more than offset by the high cost of waste disposal. Whenever possible, consult a local chemical exchange. The material you need may be available for little or no charge in your district.

Whenever possible, less hazardous chemicals should be substituted in experiments.

The wise teacher never accepts donated or cut-rate materials without academic justification. Frequently, companies will try to 'donate' their unused stock of chemicals to a school. Although this seems to be a good way to obtain chemicals, it usually provides a much greater quantity and assortment of chemicals than any lab can use in a year or two. This means that the school becomes responsible for storing and ultimately disposing of this large inventory of chemicals.

There is a great deal of interesting chemistry involved in the preparation of waste for disposal. It might be a good technique to involve the class in planning the best way to dispose of a given solution from an experiment. "Prudent Practices....." contains many useful recipes for the treatment of a variety of wastes. A few are outlined below.

DISCLAIMER

No chemical procedure can be guaranteed "safe". All experiments recommended in this manual appear to present minimum hazards. However, there is no guarantee, expressed or implied, that an experiment or procedure will not cause injury. Each teacher selecting an experiment should try it out under carefully controlled conditions before using it as a class exercise. Any necessary safety precautions should be added to the material given to the students. Activities which cannot be deemed safe for students should be altered in their delivery mode, have additional safety factors added or be deleted totally.

Recovery of Mercury

Consult the **STOP: Safety First in Science Teaching** manual distributed by the NC Department of Public Instruction. For special assistance, contact the NC Department of Human Resources, Occupational Health Division, P.O. Box 2091, Raleigh, NC 27601 (919) 733-3680

Recovery of Silver

The Ag^+ containing solution is adjusted to pH 2 with 6M HNO_3 and then treated with excess aqueous NaCl. The AgCl precipitate is suction filtered, washed twice with warm 4N H_2SO_4, twice with water and then dried. The dried AgCl is ground to a fine powder. A sample of 100 g of the dried powder is mixed thoroughly with 50 g of granulated zinc. In the hood, the mixture is stirred with 500 mL of 4N H_2SO_4.

> **CAUTION!** *This procedure generates explosive hydrogen (H_2) gas! Work in a hood away from any source of ignition.*

When all of the zinc has dissolved, the supernatant solution is removed and the treatment with 50 g granulated Zn and 500 mL of 4N H_2SO_4 is repeated. After the zinc has dissolved, about 5 mL of concentrated H_2SO_4 is added carefully, and the mixture heated to 90°C with stirring for a few minutes.

The precipitated silver is recovered by filtration and washed with distilled water until the washings are free of sulfate ($BaCl_2$ test). A sample of the silver should give a clear solution in concentrated HNO_3. If any turbidity is found, the procedure with zinc and 4N H_2SO_4 should be repeated.

The procedure generally produces silver of 99.9% purity. If local regulations permit, the zinc solution may be poured down the sink. If regulations forbid this, the zinc should be precipitated as the carbonate salt and saved for the next hazardous waste pick-up.

Carbon Disulfide (CS_2)

Since carbon disulfide is quite volatile (b. 46°C), extremely toxic, and forms ignitable or explosive mixtures with air, it poses a special disposal problem. Small quantities (100 mL or less) may be decomposed under controlled conditions according to the equation

$$CS_2 + 8\,OCl^- + 2\,H_2O \longrightarrow CO_2 + 2\,H_2SO_4 + 8\,Cl^-$$

For each 30 mL (0.5 mol; 38 g) of CS_2 , a 25% excess of hypochlorite is used in the form of 6.7 L of laundry bleach (*e.g.*, CLOROX™), or, a mixture of 550 g of 65% calcium hypochlorite in 2.2 L of water. The reaction temperature should be regulated to 20-30° C to avoid volatilizing the CS_2.

Working in a hood, the bleach solution is placed in a 5 L flask which is stirred and which contains a thermometer. The CS_2 is added dropwise from an addition funnel. The reaction usually starts quickly and is noted by a rise in temperature. Adjust the temperature by adjusting the drop rate.

If the reaction has not started when 10% of the CS_2 has been added, stop the addition and raise the temperature to 40-50° C to get it started. Only after it is obvious that reaction is occurring should the addition of CS_2 be resumed. Failure to proceed as above could result in an uncontrolable reaction.

Addition usually takes about an hour, after which the mixture is stirred for another 2 hours while the temperature gradually falls to ambient. The product should be a clear liquid with a few drops of an oily by product. Many local regulations permit the mixture to be flushed down the drain without decomposing the excess bleach. Consult your local water and sewer authority.

Inorganic Cyanides

Small amounts of cyanide may be oxidized to the relatively innocuous cyanate by aqueous hypochlorite.

$$NaCN + NaOCl \longrightarrow NaOCN + NaCl$$

Consult "Prudent Practices for Disposal of Chemicals from Laboratories" for complete details of this and many other similar disposal reactions.

Strong acids

(Other than sulfuric acid) Working in a sturdy plastic container in a well functioning hood, dilute the acid 1/1 with cool tap water. (Remember, always add the acid to the water!) Neutralize the diluted acid by slowly adding agricultural lime. Check the pH of the final solution. Solutions with a pH range 6 -10 may be flushed down the drain.

Sulfuric acid

Neutralize with a large amount of sodium carbonate or sodium bicarbonate in the same manner as above. **CAUTION!** vigorous evolution of CO_2 bubbles will occur. Work slowly and in a well functioning hood. Reaction is complete when the bubbles stop being produced.

Strong Bases

The procedure is basically similar to that for strong acids. However, there is no really cheap source of acid for the neutralization reaction. Muriatic acid, from the hardware store, is probably the least expensive acid readily available.

Other Chemicals

For additional specific procedures for the in-house treatment of of about 1,000 different chemicals, consult "Guide for Safety in the Chemical Laboratory", Manufacturing Chemists Association, Van Nostrand-Reinhold, New York, NY 1972 However, since the date of publication (1972), most of the hazardous waste regulations have been developed. Be sure to consult your local regulations to be sure that the new waste you are creating will be acceptable for sewage disposal.

A more recent listing of in-house disposal methods for a wide variety of chemicals is found in M.A. Armour et al., "Hazardous Chemicals: Information and Disposal Guide" (see Bibliography).

VII. Hazardous Materials Spills

One of the most dangerous encounters a teacher or student will have with a hazardous material is in the event of a spill. With any uncontrolled release there is a real potential for personal injury and property damage. When a spill occurs in a lab setting, it requires immediate and effective attention. This means that the only way to be prepared for a spill is to predict that one may happen and plan for it. In the great majority of cases, the planning will be for naught. However, when a spill does occur the price of the prior planning will be invaluable.

Containment

Usually a spill is only a major problem if it is uncontrolled. Work over a contained area, whenever working with a liquid or particularly hazardous solid. One of the best containment devices is the chemical resistant plastic "baking sheet". The continuous up-turned edges provide adequate, immediate containment for any fluid that might be spilled on it. This primary containment allows the teacher or student to stop the operation, put away any unusual hazards, don protective gear and work at a reasonable pace to clean up the spill. The panic that so often aggravates a minor accident has been removed.

Such containment devices have many uses. Anytime mercury is stored in glass, the glass container should be placed inside another plastic container of a volume greater than that of the mercury. In this way, if the glass breaks, the mercury is still held. These useful containers can made from common plastic bleach containers or other plastic bottles by simply cutting away the top to leave behind a homemade plastic beaker.

Information on How to Clean Up a Spill

For every chemical in a school, there should be a Material Safety Data Sheet (**MSDS**) easily available in the same area in which the chemical is to be used. These sheets which OSHA requires every chemical manufacturer to supply to purchasers of chemicals contain a wealth of information on that one chemical.

An **MSDS** is composed of nine major sections:

Sec. 1 - Material Identification

Sec. 2 - Ingredients and Hazards

Sec. 3 - Physical Data

Sec. 4 - Fire and Explosion Data

Sec. 5 - Reactivity Data

Sec. 6 - Health Hazard Information

Sec. 7 - Spill, Leak, and Disposal Procedures

Sec. 8 - Special Protection Information

Sec. 9 - Special Precautions and Comments

Careful reading of the **MSDS** of each compound involved in a laboratory experiment should be a part of the minimum planning for the experiment. From the **MSDS**, the teacher will quickly glean the necessary materials and protective gear to have on hand should a spill occur. Interesting information found on the **MSDS** may be a good "attention getter" and provide interesting background material the teacher could use to improve the discussion of the experiment.

Proper Perspective

Spills are another area of chemical handling that must be taken in proper perspective. If a tank car of sulfuric acid is ruptured on an overpass that crosses a major roadway or waterway, that is a disaster. However if 5 mL of concentrated H_2SO_4 is spilled on the counter top of a high school chemistry lab, that is a situation that is easily handled if it is immediately detected. The hazards of most chemicals are directly proportional to the quantities used and to the extent of exposure. The smaller spill is of little consequence on the bench top, but of major importance if it occurs on the skin or worse yet, in the eye.

Once the inventory of chemicals has been purged of those materials which present a great hazard that is not offset by a special pedagogical need, the teacher should develop spill responses for each of the remaining chemicals. The **MSDS** presents the first source of this information. Good chemical sense is also quite helpful.

General Procedures

Many small spills can be washed away with an excess of cold tap water. The exceptions of course are the materials like Na and K which react violently with water. The use of water is not a good procedure if the spill occurs in the vicinity of electrical equipment.

In general, it is best to contain a spill with specially designed materials available from all chemical supply houses. In an emergency, clean sand, available at most discount stores for children's sand boxes, is an ideal material for forming a small dike

around the spill. The sand will also be a fair absorbent and further contain the spill. When the emergency has passed and it is time to clean up, the sand or other material used to absorb the spill must be treated as hazardous waste. Consult your local authorities and your hazardous waste contractor. Some formerly acceptable absorbents are no longer permitted in hazardous waste land fills. This may even be the case in your area for "kitty litter", one of the first cheap spill collectors. Consult your local land fill authorities.

If an experiment will use a large quantity of a hazardous material, it is a good idea to have a sufficient quantity of the appropriate "Neutralizer" prepared in advance and convenient to the laboratory. Thus, if concentrated acids are to be used, there should be a good quantity of aqueous base handy and clearly marked. In the event of an acid spill, once it is contained in a sand dike, it can be neutralized on site and easily disposed down the drain after the pH has been adjusted to 6-10. Of course, these procedures should be performed only by skilled personnel (i.e. teachers or emergency personnel, not students) who are using proper eye protection, gloves, *etc.*

It is easy to imagine many other reactions for which a "Neutralizer" can be prepared and kept handy, "just in case!". Prior planning can prevent disaster and also provides useful instructional material.

Specific procedures for coping with spills of a wide variety of chemicals are contained in M.A. Armour et al., "Hazardous Chemicals: Information and Disposal Guide," (see Bibliography).

Personnel Safety

Whenever spills occur, the most important consideration is the safety of the personnel in the area. Evacuation of personnel and immediate application of appropriate first aid when needed, should take priority. Once the personnel have been brought to safety, then the chemical should be confined and neutralized. If the spill can not be contained and presents a major danger, the area should be evacuated and the local hazardous materials team called in. The phone number of this organization should be prominently displayed next to the phone serving the laboratory area.

Never conduct any chemical operation alone or without easy access to an outside telephone!

Of course prevention is the best policy but following appropriate safety guidelines and using prudent practices will help to provide a safer environment if an unexpected spill does occur.

VIII. Experimental Design

The Survey of Laboratory Exercises (Chapter III) illustrates typical experiments found in High School Chemistry. In most of these examples it is advantageous to reduce quantities of chemical substances to significantly reduce hazardous wastes and to improve student safety. In many cases, it is also appropriate to substitute chemicals that may eliminate hazardous materials and hazardous wastes from the lab. For example, paper chromatography can be done quite effectively using Kool-Aid™ or food coloring with water as the solvent, thus avoiding the heavy metal salts often prescribed. NaCl(aq) and $AgNO_3$(aq), in dilute solution, may be reasonable choices to avoid chromate and lead compounds in a Conservation of Mass experiment. Antacid tablets and dilute hydrochloric acid provide a very reasonable recipe for a titration experiment.

Experimental Modification

For the next several years, while text book writers are slowly discovering the benefits of greatly reduced quantities of chemicals in student experiments, the high school chemistry teacher will be the person who decides to modify an existing successful experiment. This will be very time consuming, but also a very rewarding experience. Few principals will fail to see the wisdom of significantly reducing the quantities of chemicals bought and stored. When carefully presented, these projected savings can be the leverage needed to obtain the necessary "start-up" money to begin small scale experimentation or other favorite projects.

Most students who volunteer for extra lab work, or after-hours "research" generally appreciate the advantages of working on a small scale and enthusiastically test experimental scale reductions. Their enthusiasm will help to encourage the teacher to persevere. When word of their 'adventures' gets around the school, significant student body and parental support for change to reduced scale experimentation can be anticipated. Arranging for suitable speakers to discuss chemical hazards and the merits of reduced scale experimentation at faculty meetings and PTA meetings is also likely to gather significant support for such changes in the lab program.

Mini-Scale Experiments

It is an unusual experiment which will not produce good results when the quantities are reduced by a factor of 50%. This scale of reduction, can usually be performed using the same glassware as traditionally used for the 100% experiments. Such a reduction will definitely lead to a 50% reduction in the costs of chemicals for the experiment, a corresponding reduction in the costs of waste disposal and increased safety of the teacher and students. Such trials also constitute an excellent

sign of the teacher's sincere interest in promoting student safety. This can be a great benefit in the case of a professional liability litigation involving that teacher and an unrivaled lesson in ecological responsibility for the students.

Teachers are urged to experiment with their current laboratory exercises. Are there any experiments that will not produce good results at a 50% reduction in scale?

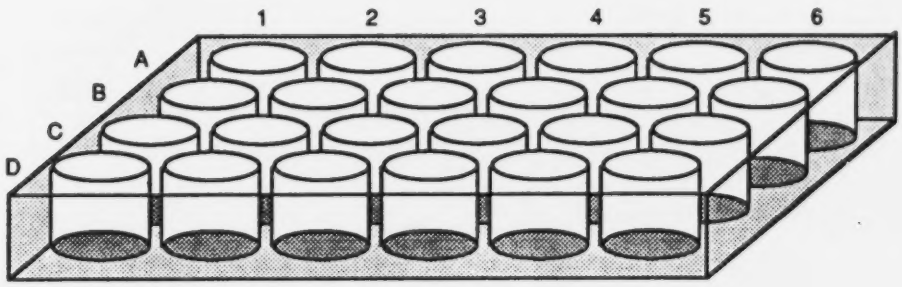
MICRO-SCALE EXPERIMENTS

When greater scale reductions are desired, the glassware usually must be changed. However, there are many different options available which vary in cost.

Plastic Ware

Probably the most cost effective means of converting to Micro-Scale experimentation is to use the plastic tissue culture plates and plastic Beral pipets that are available from numerous suppliers. Since most high school experiments are performed using water as the solvent, there is little concern about the chemical stability of the plastic. [If an organic solvent is to be used, the teacher should carefully test the reaction of that solvent with the plastic, before any student tries the experiment.] Clean up may only involve rinsing the plate with tap water and allowing the plate to air dry. There will be little or no "breakage", but if a plate is ruined from an unforeseen experiment, no significant loss is incurred since a plate costs $1.50 or less.

Many varieties of plastic spot plates are available from chemical supplyhouses. The most common are the 8,12, 24 and 96 well transparent plastic plates. A typical example is shown below.



Typical 24 Well Plate (Drawing reproduced with permission form "Microscale Laboratory Manual for General Chemistry," by J.L. Mills and M.D. Hampton, Random House, NY, Copyright 1988.)

The spot plate consists of a grid of small, uniform cylindrical containers. In the case shown, a 6 x 4 grid provides 24 different experiment chambers, each of which has a capacity of about 1 mL. Plates are available which contain as few as 6, or as many as 96, reaction chambers. Most of them come with the rows and columns permanently marked as shown. Thus, a student can easily and unambiguously identify the site of a particular reaction. For example, **B-3** designates only one location on the plate.

Many variations of a reaction can be tried in one experiment. For example, each container in row A might contain the same volume of a standard solution. Then a second reagent might be added; one drop to column 1; two drops to column 2; *etc.* In this way, if a color change or precipitate formation is involved, kinetic experiments can be performed. Solubilities may be readily determined. Comparative reactivities of various metals to the same acid could be quickly studied. The experimental possibilities are enormous! These transparent plates can also be used effectively on an overhead projector for lecture demonstrations.

But how are the required small quantities of reagent delivered accurately and reproducibly? There are many excellent but expensive solutions to that problem. A very inexpensive solution rests in the use of disposable plastic "Beral" or, less commonly, glass "Pasteur" pipets. A typical beral pipette is shown below.

A Typical Plastic "Beral" Pipette

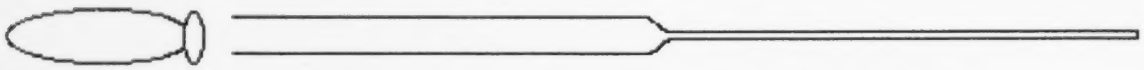
These pipettes come in a variety of sizes and shapes. Most are made of polyethylene. The type pictured is most common. The flexible 'bulb' end typically is about 3-5 mL in capacity. The narrow tube can be stretched and then cut to provide a smaller orifice which will produce a smaller drop. The pipette is usually held at about 45° to the plane of the spot plate when adding drops. Using the same technique repeatedly is required if reasonable precision is desired since drop volume varies with the angle at which the pipette is held. However, once good technique is developed, they become the Micro-Scale equivalent of a graduated pipet or titration burette.

These Beral pipettes can also be used as dispensing devices for premixed solutions or reactive chemicals. If the solution is air sensitive, the pipette can be easily heat sealed to slow decomposition, and then the tip removed just before use. One 3 mL pipette can often contain the total supply of a reagent for a class of 20-25 students!

The set of reagents for an experiment can be conveniently stored in Beral pipets kept in plastic audio cassette cases. In this way, one small shelf can hold all of the chemicals for a semester.

Micro-Scale Glassware

The next most expensive option, is to purchase very small test tubes (3" or smaller) and disposable Pyrex™ Pasteur pipets. With this equipment, everything looks like it does in a present laboratory except that it is much smaller. The same experiments can be run, the sample can be heated with a micro burner, and



Rubber Bulb and Pasteur Pipet used in Micro-Scale

measurements are usually in numbers of drops or, less frequently, in mg measured on an electronic balance. For approximate work, the 9" Pasteur pipet can be 'calibrated' to deliver 2.0, 1.5, 1.0, 0.5, 0.25, and 0.1 mL with little difficulty due to the precision with which they are mass produced. A typical "approximate calibration" drawing is shown on the next page.

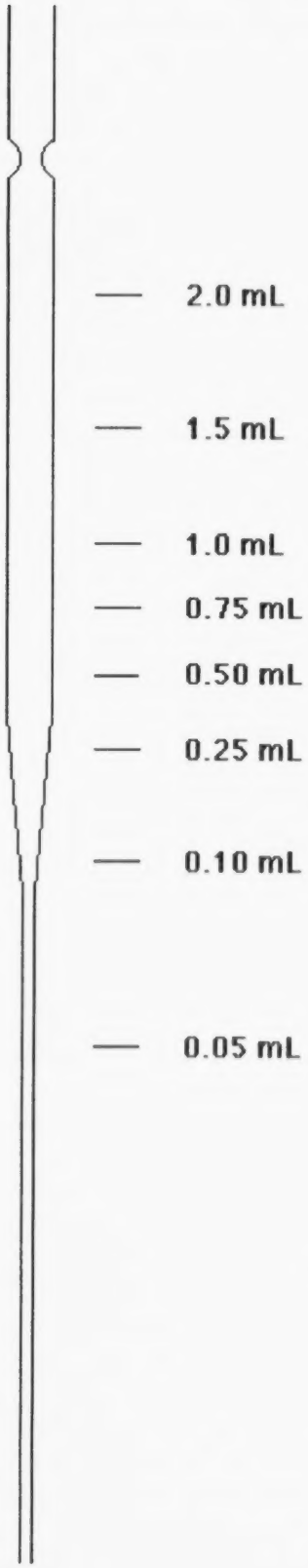
Glassware Kits

College level organic chemistry has been the first course to convert to microscale. This has been done for the same reasons as high school courses: safety, cost of chemicals, and cost of waste disposal. Experiments are done on 1/100th to 1/1000th the traditional scale and all heating is done with electrically heated sand baths, metal blocks or similar flame-free devices.

Two different styles of glassware are available for these microscale experiments. Standard-taper ground-glass joints are used in the glassware for the experiments in Mayo, Pike and Roberts' book Microscale Organic Laboratory. The components of Williamson's kit (used for Microscale Organic Experiments, and, Macroscale and Microscale Organic Experiments) are held together with less expensive connectors made of a heat and chemically resistant rubber-like material. The Williamson kit is much less expensive.

The more common standard-taper ground-glass joint kit uses very small round bottom flasks (5 or 10 mL) , but mainly cylindrically shaped reaction vials with conical bottoms in sizes 5, 3, 1, 0.3, and 0.1 mL. These are connected to the other pieces of equipment (condensers, drying tubes, distillation columns, *etc* .) with different types of connectors depending on the supplier.

While these kits are the most expensive option for the high school program, they may well be a good choice for the smaller, advanced classes. They are about the same price as the normal glassware kits that they are replacing in college laboratories. A tabulation of the sources of the different small scale equipment is included only



Approximate Calibration of 9" Pasteur Pipet

A similar calibration can be made for any pipet. It is a great time saver and allows good accuracy for semi-quantitative work.

as a starting point for the purchase of equipment. More and more suppliers are entering this growing market. The interested teacher should consult other catalogs and colleagues for additional sources.

Even though hazardous wastes will still be generated in many lab exercises, the choice to fully Micro-Scale the technique will significantly reduce hazardous waste production. A reduction of hazardous waste by one-one hundredth to one-one thousandth is not uncommon.

While microscaling is an effective technique for many of the qualitative experiments, it can be an equally effective substitute for the quantitative lab. The equipment necessary for complete microscaling includes an electronic digital balance, a digital micro-pipette, a melting point apparatus, and Micro-Scale glassware. The digital balance should have a precision of ±1 milligram. One balance is sufficient for a lab with 15 students. The micro-pipette can allow for the use of accurate volumes less than one milliliter and the mass can still be measured on the digital balance. Melting points can be determined quickly and efficiently with a Micro-Scale melting point apparatus.

However, existing equipment with scaled down quantities of chemicals can also significantly minimize the quantities of waste produced. This also permits use of the common centigram balance but still produces useful and typical quantitative results. This reasonable substitute for true microscaling will reduce quantities without requiring the purchase of new glassware and still satisfy the goal of minimizing student and teacher exposure to hazardous materials.

No matter which option is chosen, the direction is clear, when deciding on the quantities of chemicals to use -

Less is Better.

There is no reason to continue doing experiments on the 'Macro-scale'. With a little planning, all current experiments can be converted to "Micro-Scale" and run on 1/10 to 1/1,000 of the present scale with great reductions in the cost of chemicals, the potential for accident, and the quantities to be disposed.

Inexpensive Ways to 'Micro-Scale'

Some ideas gleaned from Williamson's Microscale Organic Experiments that are applicable to High School experiments include the use of flexible, small diameter polyethylene tubing (instead of bent glass tubing) to transfer gases from place to place; the use of Dowex 50X™ strong acid ion exchange resin instead of concentrated sulfuric acid as a catalyst for the preparation of esters; the use of charcoal in pellet form to adsorb a dye from aqueous solution; the use of "multifiber' test cloth" [cotton, Dacron, Orlon, nylon, rayon, wool] to show how different fibers give different colors when dyed with the same dye.

Supplies and Special Apparatus

Efforts at developing classroom experiments have been aided through biotechnology research which utilizes enormous amounts of inexpensive, disposable plastic laboratory ware. This section is included in the spirit of getting teachers started. It is not complete. New suppliers are constantly coming into the market place. [*Catalog numbers are shown in italics.*]

Suppliers

Sargent-Welch
P. O. Box 1026
Skokie, IL 60077
(800)-SARGENT

J. & H. Berge, Inc.
4111 South Clinton Ave.
S. Plainfield, NJ 07080
(201)-561-1234

Flinn Scientific
P. O. Box 219
Batavia, IL 60510-0219
(312)-879-6900

Fisher Scientific
P.O. Box 40339
Raleigh, NC 27629
(800)-662-7600

Cole Parmer Instrument Co.
7425 North Oak Park Avenue
Chicago, IL 60648
(800)-323-4340

G. Markson Scientific
7815 S.46th St.
Phoenix, AZ 85040
(800)-523-5114

Curtin Matheson Scientific, Inc.
357 Hamburg Turnpike
Wayne, NJ 07470
(201)-942-3300

Thomas Scientific
99 High Hill Rd.
Swedesboro, NJ 08085
(800)-345-2103

Flow Laboratories
7655 Old Springhouse Road
McLean VA 22101
(800)-368-FLOW

Bio-Rad
1414 Harbor Way South
Richmond, CA 94804
(800)-227-5589

Plastic Pipets

Sargent, *S-69684-14C*, 5 mL capacity
Flinn, *AP 1444*, 4 mL "Thin stem pipets"
Cole-Parmer, *TZ-6266-06*, "Thin stem pipets"
Berge, *71-5199-611*, Sedi-pet long stems
Fisher, *13-711-6*
Curtin, *036-715* Beral pipets

Markson, *GM-17457* Thin stem pipet
Bio-Rad, *223-9523* (Style D)
BioRad, *223-9522* calibrated (0.25 mL in stem); 223-9529 (0.5 mL)

Pasteur Pipets

Sargent, *S-69647-30A*; *S-69647-31A*
Fisher, *S34792* disposable glass pipets
Thomas, *7760-A50* (5 3/4" long); 7760-A60 (9" long)

8-Well Strips; 12-well Strips

Sargent, *S-70043-A* (8 wells); *S-70043-B* (12-wells)
Flinn, *AP 1446* (12-wells)
Flow, *78-591-99* (12-wells)

Latex Rubber Bulbs (for Pasteur Pipets)

Sargent, *S-73155* (2 mL capacity)
Berge, *74-7300*

Tissue Culture Flasks (solution bottles)

Flow, *LX5375*, 250 mL, 100/case
Flow, *LX5380*, 650 mL, 32 case

96-well Microplates

Sargent, *S-70014* flat bottom plates
Flinn, *AP 1448*, flat bottom plates
Flow, *76-331-05*, flat bottom plates, nonsterile, wo. cover
Flow, *76-341-05*, U-bottom plates, nonsterile, wo. cover
Thomas, *9383-N60*, U-bottom 96 well TC plate
Berge, *H21-7377*, Tissue culture plates

Pipet Tips

Sargent, *S-69722-AA*, pipet tip, Eppendorf, yellow, volume 25mL/drop
Bio-Rad, *223-9035*, Type 35, "BR" bulk tip

MicroCentrifuge Tubes

Bio-Rad, *223-9501*, 1.5 mL microcentrifuge tube with cap
Bio-Rad, *223-9500*, 1.5 mL polypropylene test tube wo. cap
Bio-Rad, *223-9490*, Cap '1.5', white caps for above tubes

IX. Representative Modifications of Popular Experiments

CAUTION: Before any experiment is used for the first time, it should be tried by the instructor who should be alert for the presence of unusually hazardous materials or for the presence of dangerous procedures. Extra written safety instructions may be prepared and given to the students prior to the time they perform the experiment.

These same considerations are important whenever modifying any experiment, particularly if a new substance is to be used. This is demonstrated by the following report:

The MORBIDITY AND MORTALITY WEEKLY REPORT of the U.S. Public Health Service's Centers for Disease Control of March 18, 1988 describes an incident in a Connecticut High School laboratory where 22 students and a teacher were exposed to hazardous levels of mercury. Because silver oxide was not available, the teacher substituted mercuric oxide in an experiment. Each student heated 1.75 g over a Bunsen burner for 15 min with the expectation of obtaining 1.62 g of mercury. There were 11 student stations and fume hoods were not used.

When low yields were obtained, it was recognized [TOO LATE!] that mercury was volatilizing. The experiment was stopped and the laboratory evacuated and ventilated. Condensed mercury on laboratory surfaces required cleanup before the laboratory could be reused.

Three days after exposure, eight of the 23 persons exposed had measured levels of mercury in urine above 30 µg/L, the maximum level considered acceptable. Six weeks later, six of those students still were high. A retest of the others showed that some were also high. Three months later one student still tested high!

The following modifications of several typical high school laboratory experiments are based on the protocols used by Metcalfe *et al.* in the Holt Modern Chemistry Lab Manual. They were developed and were completed by the committee. The focus was on providing a model for reducing quantities of reagents and there-by reducing storage, disposal, hazardous waste production and student exposure to hazards, without reducing the laboratory experience of the student.

From: Metcalfe, *et.al.*

1) **EXPERIMENT 3** : Energy and Entropy : Phase Changes

[A 10 g. sample of acetamide in a test tube is heated in a hot water bath. The sample temperature is recorded at 15 sec intervals until the sample melts. The test tube is then removed from the bath and similar data is recorded as the sample cools.]

The same protocol was used as in the manual, but student involvement is now possible. The reagent used was p-dichlorobenzene. Quantities are reduced from 10g

to 2g. Test tube size was decreased to no greater than 13mm x 100mm.

Results: This exercise produced the normal cooling curve in approximately four minutes. The melting curve, although not completed in this exercise, would be equally demonstrable, but would probably take 10-15 min. Additional benefits are derived from a lowered volume of the boiling water necessary to produce melting, and the small time interval that is required for such a reduced quantity of the reagent to solidify in air.

2) EXPERIMENT 7: Water of Crystallization and Empirical Formula of a Hydrate

[Various hydrates are weighed to the nearest 0.01 g. before and after heating in a crucible. From the weight loss, the number of "waters of crystallization" are determined.]

The same protocol as in the manual was used, and a 10x75mm test tube was used as the reaction vessel. Care is needed to evaporate the water from the lip of the tube. A 1g sample of magnesium sulfate ($MgSO_4 7H_2O$) was used. **Note:** All weighings should be completed as soon as the reaction vessel is cool enough for the balance pan to minimize reabsorption of water.

Alternative reagents: Plaster of Paris ($CaSO_4 1/2H_2O$) may be substituted for Copper Sulfate ($CuSO_4 5H_2O$), and Barium Chloride ($BaCl_2 2H_2O$) which are toxic if ingested and are skin irritants. However, since they have less water of hydration to lose, they require more careful lab technique, and a more accurate balance, to obtain good results.

Results: This trial yielded very acceptable results (within 5% of the expected). The primary advantage, in addition to reducing the reagents needed, is in the shorter time required for completion.

3) EXPERIMENT 8: Mass and Mole Relationships in a Chemical Reaction

[A known mass of sodium bicarbonate in an evaporating dish is reacted with hydrochloric acid, heated to dryness, cooled and weighed to get the mole ratio of NaCl obtained to $NaHCO_3$ reacted. A balanced equation is then developed.]

This experiment is a good example of one that can be mini- or micro-scaled. All quantities at the mini-level can be reduced by at least half. This not only reduces the amount of reagent used, but also reduces lab time by reducing the evaporation time. Also, the reaction vessel (presently a crucible and cover) can be a larger beaker (250mL) in which more surface is exposed for evaporation of the water, and no cover

is required since losses through spattering are not such a problem in a vessel of this volume. The micro level is a bit more complex because of its requirement for a digital balance(+/- 0.001g). The quantities required per student for this reaction are: 1.0mL 3M HCl and 150mg $NaHCO_3$. Also, because of its reliance on smaller reaction vessels, this technique adapts well to the time constraints of the typical high school lab.

Results-Mini-Scale: This exercise yielded an experimental error of ±8%, a value magnified by the use of the centigram balance yet well within acceptable levels for the high school teaching laboratory. Also, it was found that by using such small quantities (1g in this instance), the time required for the neutralization and subsequent evaporation of the solvent was reduced to approximately 15 minutes.

Results-Micro-Scale: The micro level was as productive as the mini-reductions; yet, the experimental error was reduced to ±2%. The time factor was not significantly reduced from usual high school lab technique, however, due to the extreme care needed to prevent boil-over in the micro equipment.

4) EXPERIMENT 2 (in Smoot) - Investigating the Law of Conservation of Mass-Energy

[Potassium chromate and lead (or silver) nitrate solutions are reacted. The lead chromate precipitate is filtered, dried and weighed. The potassium nitrate solution is evaporated and the solid residue (KNO_3)is weighed.]

To make this lab less dangerous, the lead chromate and lead nitrate compounds can be substituted by 0.5 M Na_2CO_3 and 0.5 M $CaCl_2$ solutions. Equally dramatic results are routinely obtained. Typical student results consist of 0.07 to 0.01 g reactant to product differences even with a centigram balance.

From the foregoing examples, it should be apparent that only minor modifications are needed to reduce the standard high school experiments to mini- or micro-level. This reduction in the quantities of chemicals used, reduces the students' exposure to hazardous materials without diminishing his 'hands-on' experience with chemicals and lab experimentation. The down scaling not only reduces inventory requirements and the costs of purchasing chemicals, but also greatly reduces the amount of hazardous waste that each experiment generates. There appears to be no significant limitation to the application of this reduction in size to any experiment. Teachers are encouraged to scale down their favorite experiments and determine how well the mini or micro version works.

Several other experiments are offered as general examples of small scale reactions, well suited for the constraints of the high school laboratory, which produce little if any hazardous waste.

"KOOL-AID™ Chromatography"

An Environment Friendly Paper Chromatography Experiment

NOTE TO INSTRUCTOR

Dissolve one package of KOOL AID™ in 10 mL of water in a 100 mL beaker. (This produces a very concentrated solution needed to see each dye.) Repeat with another flavor to produce a second solution. Each student uses a spot of each solution. Use Grape and Lemon-Lime since each contains a common blue dye, or, Orange and Lemon-Lime which contain a common yellow dye. Water soluble blue and black inks also work well. The chromatogram takes about 12 minutes to develop.

The many types of Chromatography are of great importance in research and analytical laboratories. They can be simulated in the student laboratory very inexpensively and with good success. This experiment poses no hazardous waste problems since it uses only water and KOOL-AID™. The results are both surprising and explainable.

The measurable in this experiment, the Retention Factor or R_f is the factor by which the components of a mixture may be identified and is defined as

$$R_f = \frac{\text{Distance Traveled by Solute}}{\text{Distance Traveled by Solvent}}$$

Equipment

250 mL Beaker	Glass Stirring Rod	
Chromatography Paper	Tape	
Centimeter Ruler	Graduated Cylinder	Pencil

Procedure

1. Measure 15.0 mL of tap water with the graduated cylinder. Pour the water into the beaker

2. Obtain an 8 cm piece of chromatography paper. Make sure it will reach from the water to nearly the top of the beaker. DO NOT put the paper in the water yet!

3. Draw a pencil line on the paper about 2 cm above the water level. Put one dot of each of the concentrated KOOL AID™ solutions on the line about 1 cm apart. Label each dot according to the flavor it is.

4. Tape the other end of the paper to the center of the glass stirring rod. Suspend the

paper above the water in the beaker. Make sure it does not touch the sides of the beaker and that the dots are just above the surface of the water. Record your observations.

5. Allow the chromatography to develop until the water has almost reached the glass rod.

6. Remove the paper carefully and make a pencil line to show the upper limit of the water as it proceeded up the paper. Allow the paper to air dry by placing it on a paper towel.

7. Each student should run a chromatogram for his/her report.

Calculations

Determine the R_f for the Blue Dye in each of the flavors of KOOL AID™ by measuring the distance from the initial line to the top of the blue spot, and then measuring the distance the water traveled from the initial line. Record all of your measurements and calculations.

Questions

1. Explain how you used chromatography in this experiment.

2. Why did some dyes move far up the paper while others stayed closer to the initial line?

3. What were the **solute** and **solvent** in this experiment?

4. Can you suggest a reason for using unsweetened KOOL AID™?

5. What can you determine from the R_f values that you calculated for the spots from each flavor of KOOL AID™?

6. Why were the dots of KOOL AID™ not supposed to touch the water?

7. This experiment demonstrated a physical change. Explain briefly how this was a physical change.

8. What physical property allowed you to accomplish this chromatography?

Woodrow Wilson - NSF/Dreyfus Program

The following experiments are from the recent Dreyfus Program supported by the National Science Foundation (NSF) and the Dreyfus Foundation, and administered by the Woodrow Wilson Foundation, P.O. Box 642, Princeton, NJ 08542 (609) 924-4666. Ms. Nancy Arnold is the Program Officer. Dr. Jerry Bell, Simmons College, 300 The Fenway, Boston, MA 02115 (617) 738-2186 directed the NSF/Dreyfus Summer Institute. This has been the strongest force in introducing Micro-Scale to the high school lab. These experiments are offered as additional examples of experiments that may suggest ways to reduce the quantities in experiments in other high school experiments.

The actual examples used here have been generously supplied by Dr. David W. Brooks, Center for Science, Mathematics and Computer Education, 118 Henzlik, University of Nebraska at Lincoln, Lincoln, NB 68588-0355 (402) 472-2018. Dr. Brooks and colleagues organized a follow-up workshop of Nebraska high school teachers during the Summer of 1988. At that activity, 43 of the 1987 NSF/Dreyfus experiments were refined and rewritten.

Four "typical" Micro-Scale experiments are included here as representative examples of how good chemistry can be taught with very small quantities of chemicals. The interested teacher is directed to the full 43 experiments mentioned above, and to the lab manuals written by Mills and Hampton, and by Thompson [see, Bibliography, Sec. IV] for additional experiments.

The Formula of a Compound

Introduction:

The purpose of this experiment is to determine the nature of the solid compound formed in the following reaction:

sodium hydroxide(aq) + cobalt chloride(aq) ---> a precipitate + a solution

Once the formula of the precipitate has been determined, you will be able to establish a balanced equation for this reaction.

The technique used in this experiment is called a precipitate titration. Cobalt ions, Co^{2+}, from the cobalt chloride solution will react in a set ratio with the hydroxide ions, OH^-, from the sodium hydroxide solution. This combination will form a precipitate of the compound in question. The sodium and chloride ions will stay in solution. An indicator is added which will change color when the OH^- ions are no longer able to react with the Co^{2+} ions. This will occur when all the cobalt ions have been consumed in the formation of the precipitate. The color change is called the end point of the titration.

Safety:

Wear aprons and eye protection at all times during this experiment.

Use extreme caution with sodium hydroxide solutions. Sodium hydroxide is caustic to tissue and causes blindness. Wash spills immediately. Cobalt compounds are toxic. Do not ingest any chemicals. Wash spills immediately with water. Wash hands before leaving the laboratory.

Procedure:

1. Set up a hot water bath.
2. Heat the pipets containing the cobalt chloride and sodium hydroxide solutions in the water bath for 15-20 seconds. (Holding the dropper ends with forceps will prevent burns.)
3. Select a 12-well strip. Add 1 drop of 0.1 M $CoCl_2$ to well 1, 2 drops to well 2, etc., until you add 8 drops to well 8.
4. Add 8 drops of 0.1 M NaOH to well 1, 7 drops to well 2, *etc.*, until you add 1 drop to well 8.
5. Add 1 drop of 1% phenolphthalein solution to each well.
6. Stir each well with a toothpick.

7. Permit the mixtures to settle for 10 minutes. Select a second 12-well strip. Use a Beral pipet to remove a small amount of the liquid from above the precipitate in the first well and transfer that liquid to the corresponding well in the fresh strip. Rinse the transferring Beral with water. Repeat this process until a sample has been obtained for each well.

8. Add 2 drops of NH_4SCN to each of these wells containing the transferred liquid.

9. Test NaOH with both phenolphthalein and NH_4SCN. Test $CoCl_2$ with both phenolphthalein and NH_4SCN. (Use unoccupied wells on the 12-well strips.)

10. Repeat the procedure if time permits.

11. Save the cobalt residues for disposal with heavy metal wastes. Clean your equipment. Wash your hands.

Calculations and Questions:

1. Determine the ratio of the drops of Co^{2+} needed to react with the drops of OH^- to form cobalt hydroxide precipitate.

2. Assuming that the concentrations of the two reacting solutions are the same, explain the meaning of the drop ratio calculated in question #1.

3. From your answers to questions 1 and 2, what would be the ratio of Co^{2+} ions to OH^- ions in the precipitate, cobalt hydroxide? (Round off your answer to the nearest whole number.)

4. Write the formula for cobalt hydroxide which you have determined in this experiment.

Discussion:

1. Having experimentally determined the formula for cobalt hydroxide, is this formula reasonable considering the charge balance of the compound. Support your answer.

2. Using the formula for the precipitate product you established, complete the original equation for the reaction. Use chemical symbols in place of words.

3. State the meaning and importance of the results obtained from the test for the presence of cobalt ions in the reacted solution.

4. If you could use only one of the trials, which would you choose? Why?

Teacher's Guide
The Formula of a Compound

Description:

The formula for the precipitate resulting from mixing cobalt chloride and sodium hydroxide is determined by precipitation titration.

Materials:

0.10 M cobalt chloride (dissolve 2.38 g of $CoCl_2 \cdot 6H_2O$ in enough water to make 100 mL of solution)
0.10 M sodium hydroxide - NaOH (dissolve 4.0 g of NaOH in enough water to make 100 mL of solution)
1% phenolphthalein (dissolve 1 g phenolphthalein in 60 mL of 95 % ethanol and dilute to 100 mL with distilled water)
ammonium thiocyanate reagent (dissolve 5 g of NH_4SCN in 100 mL acetone; keepin glass containers, not in plastic. Do not store this solution; make fresh every few days.)
2 12-well strips
5 toothpicks
water bath (250-mL beaker with 200 mL tap water; hot plate)

Lab Hints:

This experiment should be done early in a first year course. It illustrates the concept of formula writing and equation balancing.

This procedure can be completed in the typical one hour period. This includes: (a) pre-lab introduction of purpose, technique, and safety procedures; (b) two complete attempts at the procedure; and (c) post-lab discussion of the concepts involved.

Drop sizes must be uniform in this experiment. See the special technique in which a thin stem pipet and a plastic pipet tip are combined to make a device that delivers uniform drops.

Answers:

The experimental ratio is usually 2 OH^- to 1 Co^{2+}.

This means that there are 2 moles of hydroxide for every 1 mole of cobalt(II) ions.

This results from the 2:1 ratio expected, or $Co(OH)_2$.

Reference:

The Woodrow Wilson microscale version of this lesson was developed by:

Lee Daniel
Arapahoe High School
2201 E. Dry Creek Road
Littleton, CO 80122

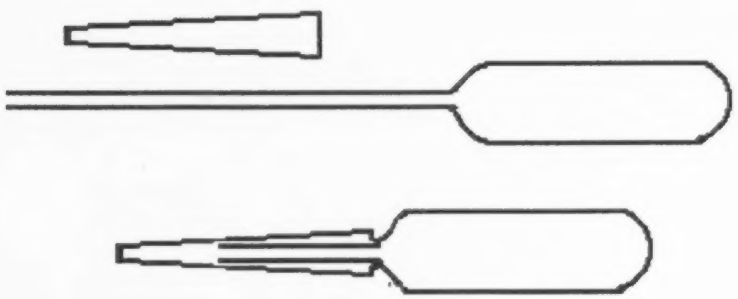
Special Technique

Description:

After the end of the Nebraska workshop (mid-July, 1988) the editors learned of an inexpensive attempt to get uniform drops and cut down on preparation time involving the use of plastic pipet tips ordinarily used with automatic pipeting devices.

Procedure:

Cut the stem of a thin stem polyethylene pipet to 1". Insert the stem



into the plastic pipet tip.

The apparatus assembled in this fashion is expected to give uniform drops from device to device assuming that the tips are identical. In other words, all students in the class will have nearly the same sized drops. The apparatus is useful for titrations and precipitation stoichiometry experiments.

Reference:

The editors learned about this technique from participants in the Woodrow Wilson 1987 summer program for chemistry teachers. In spite of several long distance phone calls, it was not possible for the editors to attribute this technique to one individual. This speaks very favorably for the impact which that single, small summer program has had upon chemistry education.

Iodine Clock Kinetics

Introduction:

The rate of a reaction is governed by the following relationship:

rate = $k [A]^a[B]^b[C]^c$

The quantities in brackets are read as moles/liter and are raised to an appropriate power. Multiplied together with the constant (k), they give the rate of the reaction.

The numerical values of a, b, and c must be determined by experimentation. These numbers determine the order of the reaction. Added together they give the over-all order of the reaction. It is the purpose of this experiment to determine the order of an iodine clock reaction with respect to H_2O_2.

The reaction to be studied in this experiment is the acid buffered oxidation of iodide to triiodide by hydrogen peroxide:

$3I^- + H_2O_2 + 2H^+ \text{ ---> } I_3^- + 2\,H_2O$

Your assignment is to study the rate of this reaction at various concentrations of H_2O_2.

Safety:

Wear lab aprons and safety glasses.

Procedure:

Work with a partner.

Practice the shake-down technique:

Fill the first 5 wells of each of 2 12-well strips with 3 drops of distilled water. Your instructor will demonstrate the "shake-down" method of mixing. Stack one strip atop the other, as in the Figure.

Holding the plates firmly together shake them once vigorously in a downward motion. This is done by flicking your hand down as fast as you can and stopping abruptly. There is no upward motion so this is a shakedown method.

Begin the experiment:

Arrange two 12-well strips so the numbers are read from left to right. Place drops of solutions into the two strips according to the following table:

Row 1: Solution A

Cell#:	1	2	3	4	5	6	7	8	9	10	11	12
Drops Soln A:	4	4	4	3	3	3	2	2	2	1	1	1
Drops Water:	0	0	0	1	1	1	2	2	2	3	3	3

Row 2: Solutions B and C

Cell#:	1	2	3	4	5	6	7	8	9	10	11	12
Drops Soln B	1	1	1	1	1	1	1	1	1	1	1	1
Drops Soln C	4	4	4	4	4	4	4	4	4	4	4	4

Prepare to time the reactions with a clock or stop watch.

Holding the plates firmly together, shake them once vigorously in a downward motion as practiced. As soon as the strips are mixed, your partner should start the timer.

The cells may not change color at the same instant. Record the "blue-time" when the second color change occurs in each group of three cells.

Repeat if necessary. This experiment does not take much time so if you miss a blue-time you can easily repeat the procedure.

The materials used in this experiment may be disposed of safely at the sink.

Report:

The rate of reaction can be represented by the following equation:

$$\text{Rate} = k[H_2O_2]^a[I^-]^b[H^+]^c$$

The concentrations of I^- and H^+ are held constant in the procedure; all wells in row 2 were filled with the same amount of solutions B and C. We may write the rate:

$$\text{Rate} = k'[H_2O_2]^a$$

Where $[I^-]^b[H^+]^c$ has been absorbed into the pseudo-rate constant, k'.

This experiment has been set up in a clever fashion. The end point color appears after all of the thiosulfate is used up. The amounts of reactant used up in causing this to take place are small, so the reactant concentrations remain essentially constant throughout the time of reaction.

The expression for the rate of this reaction is:

$$\Delta[H_2O_2]/\Delta t$$

But the concentration change at the time of the endpoint is a constant

$$3\,I^- + H_2O_2 + 2\,H^+ \longrightarrow I_3^- + 2\,H_2O$$

$$I_3^- + 2\,S_2O_3^{2-} \longrightarrow 3\,I^- + S_4O_6^{2-}$$

Therefore, the rate is related to a constant divided by the time it takes to reach the end point. Plotting $1/\Delta t$ is the same as plotting a constant times the reaction rate.

But the rate is equal to $k'[H_2O_2]^a$. Therefore, a plot of the rate versus $[H_2O_2]$ gives an indication of the exponent, a. If the slope does not change, a = 0. If there is a straight line through the origin, a = 1. If there is a parabola, a = 2.

Plot a graph of your results. Use the x-axis for number of drops and the y-axis for the reciprocal of the reaction time. Draw the best fitting curve to this plot.

Based upon the graphs, determine the order of the reaction with respect to H_2O_2.

Briefly describe how you would use variations of this lab to determine the order for the I^- and H^+.

Having determined the order for the three reactants, how would you determine the value of k?

Teacher's Guide
Iodine Clock Kinetics

Description:

The time after mixing that it takes for a mixture of hydrogen peroxide, starch, potassium iodide, and thiosulfate to turn blue is recorded and related to the concentration of certain reactants.

Materials (per class of 30 working in pairs):

Solution A: 2.0 mL of 30% hydrogen peroxide + 93 mL of distilled water. (15 mL of 3% peroxide and 80 mL of water will also work but reaction times will be longer.)

Solution B: Starch solution with 0.005M sodium thiosulfate ($Na_2S_2O_3$): Bring 100 mL of distilled water to a boil and spray in laundry starch from a spray can until a faint bluish translucence is noticeable. Cool. Add 0.124 g of $Na_2S_2O_3 \cdot 5H_2O$ in 100 mL of solution.

Solution C: 1.74 g of KI, 1.4 g of $NaC_2H_3O_2$, and 3 mL of 6M acetic acid in a total of 200 mL of water.

Place the solutions in labeled Beral pipets. (Students must use a uniform drop size to insure success.)

15 single row tissue culture plates (1 x 12 well [FB] strip TiterTek cat. No. 78-591-99)
distilled water
60 Beral pipets
15 Beral pipet holders (cassette tape cases)
clock with sweep second hand or stopwatches

Lab Hints:

A teacher demonstration is necessary to show the students the proper method of shaking the solution. During the demonstration impress upon them the necessity of holding the wells gently but firmly. The wells are mixed all at once with a snapping motion (there is no shaking up and down, as this would cause leakage). The "averaging" technique works well visually and the time increments of 20-30 seconds allow recording of data. Set up the required solutions in Beral pipets. One pipet holds enough solution for a class of 30 to run four trials.

Closure:

If the students follow instructions the solutions will turn blue in sequence from left to right in a total time of under three minutes. The times will vary from run to run but the graphs of the lines will still reliably show the order.

The reaction rate is measured by determining the time required for the reaction to consume a small amount of thiosulfate which is initially present in solution. Thiosulfate is relatively inert toward hydrogen peroxide, but is very rapidly oxidized by triiodide:

$$I_3^- + 2S_2O_3^{2-} \text{---> } 3I^- + S_4O_6^{2-}$$

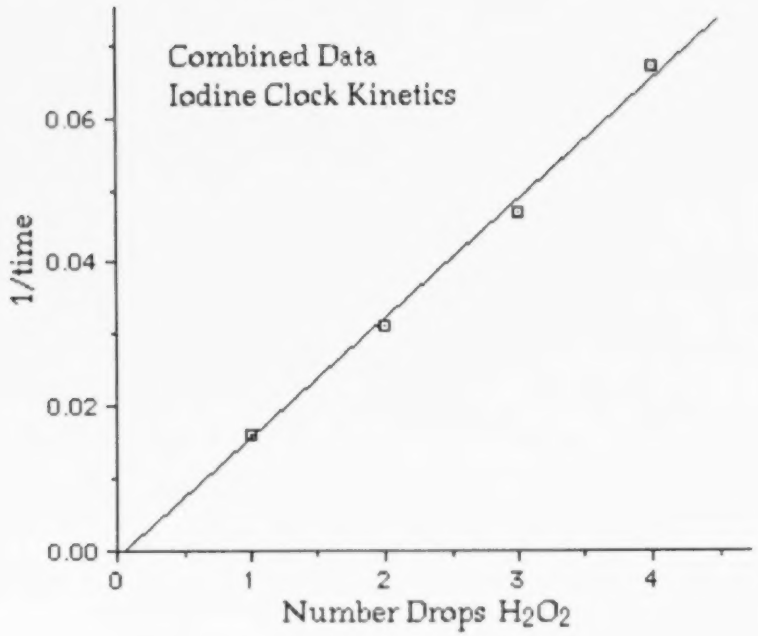
No appreciable amount of triiodide forms until the thiosulfate has been completely consumed. At this point, the starch reacts with the triiodide suddenly turning dark blue (starch iodine complex). During the process of this reaction only a negligible amount of the peroxide reacts so its initial value is essentially unchanged. The H^+ concentration is buffered and remains appreciably unchanged. The I^- oxidized by the peroxide is immediately regenerated by the reaction of triiodide with thiosulfate so the I^- concentration is unchanged during the measured time interval.

Students should be able to determine that this reaction is first order with respect to H_2O_2.

Sample Data:

Data Combined From 11 Experiments

Drops H_2O_2	Time (seconds)	$\log_e$ (drops)	1/drops
4	15.0	1.386	0.250
3	21.2	1.099	0.333
2	32.1	0.693	0.500
1	64.4	0.000	1.000



Reference:

The Woodrow Wilson microscale version of this lesson was developed by:

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Buena H. S.
Sierra Vista, AZ 85635

Richard Perry
Cottage Grove H. S.
Cottage Grove, OR 97424

Diffusion in a Tube

Background:

One gaseous substance can diffuse through another due simply to their random motion. The speed of diffusion of molecules depends on their mass. Heavy molecules diffuse more slowly than light molecules. The mathematical relationship is as follows.

R_A = rate of diffusion of gas A
R_B = rate of diffusion of gas B
M_A = molar mass of gas A
M_B = molar mass of gas B

$$\frac{R_A}{R_B} = \sqrt{\frac{M_B}{M_A}}$$

This distance travelled is proportional to the rate. If d_A represents the distance travelled on the average by a gas during a given period of time, and d_B the corresponding quantity for gas B, then

$$\frac{d_A}{d_B} = \sqrt{\frac{M_B}{M_A}}$$

Safety:

Wear eye protection and aprons. Do not ingest or touch the concentrated ammonia or the concentrated hydrochloric acid. Wash all spills with large amounts of water. Keep the concentrated chemicals under the hood.

Example:

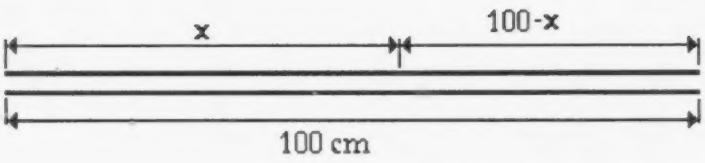
Find the rate of diffusion of N_2 compared to O_2.

$$\frac{R_{N_2}}{R_{O_2}} = \sqrt{\frac{M_{O_2}}{M_{N_2}}}$$

$$= \frac{32}{28} = 1.07$$

Nitrogen diffuses 1.07 times as fast as Oxygen.

Suppose nitrogen gas and oxygen gas, both at 25 °C, were injected into opposite ends of a tube filled with neon gas. If the tube is 100 cm long, at what point will the N_2 and O_2 meet?



You may calculate the distance from either end. We chose the end where N_2 was introduced.

$$\frac{x}{100 - x} = \frac{d_{N_2}}{d_{O_2}} = \sqrt{\frac{M_{O_2}}{M_{N_2}}} = 1.07$$

Solving for x, x = 51.7 cm and 100-x = 48.3 cm

Procedure:

Obtain a Beral pipet containing concentrated HCl at the hood. Place 2 drops of HCl in well 1 of a 12-well strip.

Obtain a Beral pipet containing concentrated NH_3 solution at the hood. Place 2 drops of NH_3 in well 12 of a 12-well strip.

Return to the work station. Grasping the middle of the capillary tube, quickly dip one end into the HCl and then the other end in the NH_3 solution. Place the tube on the black table top. Measure immediately the distance from the innermost edge of the HCl to the innermost edge of the NH_3 solution. (This is the length of the tube of air trapped between the 2 liquids.) Record this distance in part A on the Data Table.

The gases will begin to diffuse through the air in the tube. Where the two gases meet, a white ring will begin to form on the tube because NH_3 and HCl react to form the solid NH_4Cl.

As soon as the white ring forms in the capillary tube, mark the spot with the china marker. Measure how far from the NH_3 end the two gases actually met on your capillary tube. Record the value in part C on the Data Table. Using the equation in the introduction, calculate the distance where the gases were expected to meet. Show your work below and then record your value in part D on the Data Table.

Data Table:

A. Total length of trapped air in capillary tube

B. Calculated ratio of distance travelled by ammonia to distance travelled by hydrogen chloride:

C. Distance from the NH_3 end that the gases actually met?

D. How far from the NH_3 end do you predict the gases will meet?

E. Difference between actual and predicted?_____

Questions:

Explain why the gases did not meet exactly halfway between the two liquids.

Teacher's Guide
Diffusion in a Tube

Description:

The rate of diffusion of two gases is observed by measuring the distance in a tube that a precipitate forms from the source of each gas.

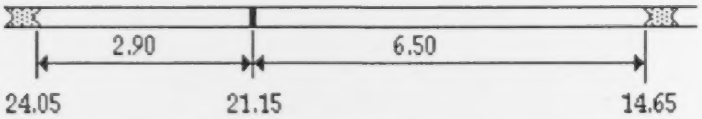
Materials:

Beral pipet filled with concentrated HCl (store in hood)
Beral pipet filled with concentrated ammonia (store in hood)
6-8 cm capillary tube
12-well strip
metric ruler
China marker

Answer:

Ammonia is lighter than hydrogen chloride and so the average speed of ammonia molecules is greater than that of hydrogen chloride molecules at the same temperature.

Sample Data:



Readings from ruler with millimeter scale

Predicted

$$\frac{d_{NH_3}}{d_{HCl}} = \sqrt{\frac{M_{HCl}}{M_{NH_3}}} = 1.47$$

Observed = $\frac{6.50}{2.90} = 2.24$

Reference:

The Woodrow Wilson microscale version of this lesson was developed by:
Donna Deen
Pauls Valley High School
111 Maxwell Drive
Pauls Valley, OK 73075

Boyle's Law

Introduction:

Gases are compressible. The quantitative relationship between pressure and volume was studied by Robert Boyle. In this experiment, you will try to discover a relationship between the volume and pressure of a sample of gas trapped in a closed hypodermic syringe.

Safety:

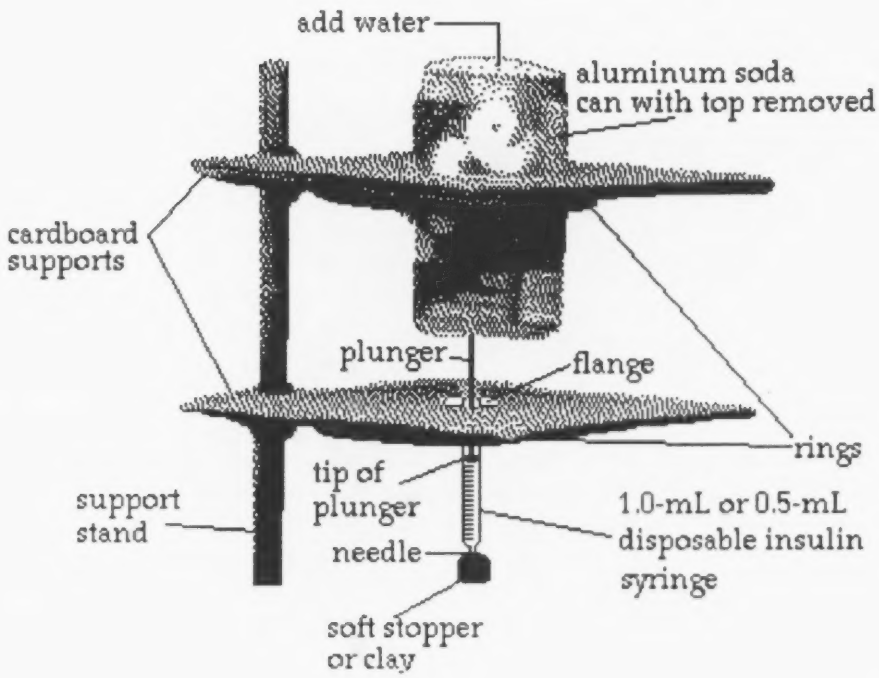
Wear safety goggles and aprons in the lab at all times. Exercise extreme caution in dealing with the needles on the insulin syringes — they are very sharp and can cause injury. Keep needles covered with clay or a soft stopper at all times. Topless soda cans can cause cuts; be careful in handling them.

Procedure:

In the center of one cardboard square make a hole large enough to accommodate the barrel of the syringe.

Secure one ring on the support stand at a convenient viewing height. Move the piston in the syringe to the 1 mL (0.5 mL for the smaller size) setting. Carefully place the syringe through the small hole in one cardboard square. Remove the needle protector and insert the needle into the soft rubber stopper (or some modelling clay). Set this assembly on the center of the lower ring. Place the second ring about 10 cm above the first ring.

In the center of the second cardboard square cut a hole large enough for the beverage can to move up and down freely but not flop from side to side. See the figure on the following page.



Find the mass of the topless empty beverage can. Add enough water to the can to make the mass of the can plus the water equal to 50 g. Place the remaining cardboard square on the top ring and pass the can through the hole and rest the center of the can on the top of the piston.

Press down on the can to force the plunger of the syringe down and then release.

Record the mass of the can and the water; record the volume of the syringe. (Do not use the data point for 0 mass and either 0.5 mL or 1.0 mL.)

Add water to the can in 50 mL increments. Record the mass and the volume each time. Continue the procedure until the total mass is 350 grams.

Disassemble the equipment carefully according to the instructor's instructions. Make two graphs of the data. On the first, graph the volume on the x-axis and pressure (mass) on the y-axis. On the second graph, plot 1/volume on the x-axis and the pressure (mass) on the y-axis.

Teacher's Guide
Boyle's Law

Description:

A setup using a small insulin syringe as a piston is used to determine the relationship between the volume and pressure for a fixed mass of gas at constant temperature.

Materials:

1 0.5–mL or 1-mL Insulin syringe
1 soft rubber stopper
1 354-mL aluminum beverage can with top removed
1 support stand
2 medium rings for support stand
2 cardboard squares, larger than the rings
1 50-mL graduated cylinder
1 triple beam balance

Lab Hints:

Be careful removing the top from the aluminum beverage can. A standard can opener will not work since the top sets well below the rim of the can. The top can be removed by carefully cutting around the inside rim with a sharp heavy duty cutting knife. You may want to put tape around the sharp lip which remains inside the can. The depression at the bottom of the can helps keep the force centered over the plunger.

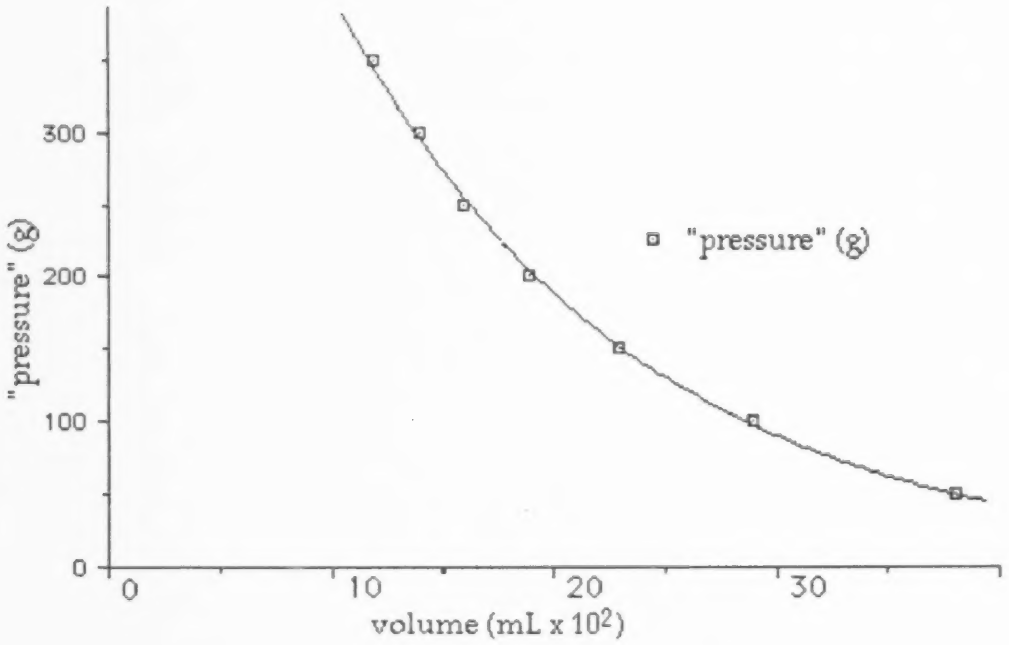
Removing most of the needles with metal snippers is possible if clay is used as the closing mechanism. This will minimize the chance of a puncture injury resulting from an accidental stabbing with the needle.

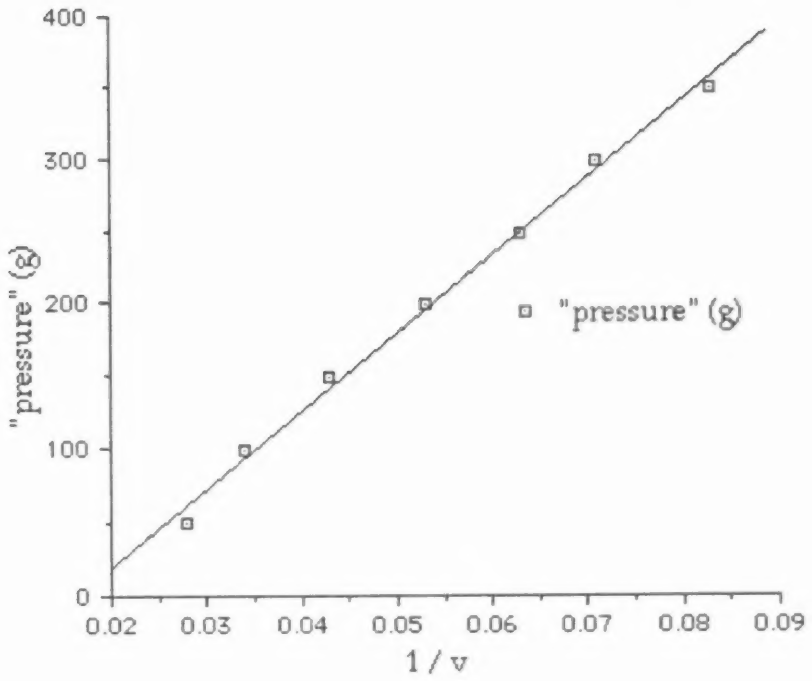
Avoid spilling water on the top cardboard support; the wet cardboard expands and causes friction.

Although mass is plotted, the actual units should be units of pressure. Pressure is force divided by area. Force (due to gravity) is given by mass times acceleration due to gravity.

Sample Data:

Mass (g)	Volume (mL x 10^2)	1/V
50	38	0.028
100	29	0.034
150	23	0.043
200	19	0.053
250	16	0.063
300	14	0.071
350	12	0.083





Reference:

The microscale version of this lesson was developed by:

Jared Ketner
Wahoo High School
Wahoo, Nebraska

X. Suggested Safety Committee Program

The current concern over safety, and present knowledge of hazardous materials and practices makes safety not only a moral obligation but both a legal requirement and an economic necessity. The following is meant only as a skeleton from which each education authority could develop specific definitions and procedures.

PURPOSE

The main purpose of a safety committee is to build and supervise strategies for safety instruction, safer working conditions, and maintenance of the environment. The safety committee should focus on advising and assisting the LEA but should not have primary responsibility for working conditions and practices.

PHILOSOPHY

Safety is the responsibility of all persons employed in the NC school system. Therefore, it is the responsibility of all employees to exercise judgment and insure that sound safety practices are followed. The attitude which requires that no consideration will outweigh the concern to prevent injuries must be encouraged. Chemistry teachers, in particular, must be always alert to possibilities for reducing the students' adverse exposure to harmful chemicals.

STRUCTURE

This committee must include everyone concerned with safety in the school. A committee might include representatives from the administration, faculty, students, central office, school bus garage and maintenance staff. Perhaps, if the group is small, a member could be included from the community—a lab chemist, a member of the American Chemical Society or a member of one of the emergency services groups in many small communities.

TRAINING

A national goal, supported by the Council of State Science Supervisors, is for all science teachers to be trained in current laboratory safety procedures. Historically, such training has not been a part of the science teacher preparation program. The safety committee should provide information on seminar and workshop opportunities to learn new safety techniques. It might build a small library of safety books, tapes and videos that might be used by teachers and students alike.

Primary Responsibilities

1. **To Prevent injuries**—Schools have a responsibility to protect the personal welfare of all their employees, students and visitors.

2. **To learn to work with and to accept the responsibility for the appropriate use of hazardous substances.** The safety committee may provide information on new developments that decrease the hazards present in teaching labs.

3. **To encourage the development of positive attitudes toward safety**. Outside speakers and upbeat videos might be arranged for teacher meetings to help the overworked teachers maintain a strong positive attitude.

4. **To develop safety procedures, policies, safety programs,** and to set reasonable and attainable future goals.

5. **To meet regularly and communicate information** pertinent to the goals of the committee.

6. **To monitor the school environment,** not in a judicial sense, but in order to assist persons in accomplishing established safety goals.

Suggested Activities

1. Invite guest speakers to group meetings and staff training sessions
2. Start a reference library of safety literature
3. Encourage participation in first aid training and emergency procedures
4. Schedule safety inspections
5. Sponsor a Safety Forum to foster creative solutions to possible or actual problems
6. Develop a newsletter or other form of regular communication (including telecommunication)
7. Evaluate texts for possible safety hazards
8. Lobby for possible funding to support safety goals
9. Present the activities of the committee to civic groups, businesses/industries, and the academic community
10. Coordinate activities to insure current and updated information is available to all who need it
11. Sponsor student safety competitions
12. The safety committee should alert the administration of all unsafe conditions as soon as they are detected.

XI. Suggested Strategies for Developing Positive Student Involvement with Hazardous Materials

It is important for students to develop appropriate attitudes for the use and disposal of hazardous materials. Students should be made aware of the hazards associated with the chemicals found in their school chemical storage facilities as well as those commonly found in homes. Several strategies are suggested for accomplishing these goals:

1. Prior to any experiment or demonstration, carefully discuss with the students the proper methods of handling and disposal of any chemicals that are to be used. Cite appropriate sources for disposal methods. A post-lab discussion would also be appropriate.

2. Assign individual students a list of several chemicals during each grading period. For each chemical on his list, the student should identify physical and chemical properties. In addition, any known hazards associated with the chemical should be listed. The overall goal would be to produce a Material Safety Data Sheet (MSDS) for every chemical listed in the school's inventory. Disposal methods, preferably "on-site" methods, should be included as a part of the report on each chemical. A list of references should be included with each report.

3. Studies of area industries could be carried out by students in small groups. Each group could visit the industrial site to learn about the use, storage, and disposal of chemicals for that company. Reports and posters would be an appropriate way to share the information.

4. Students could be assigned to make a list of any chemicals found in their homes. The project would be to investigate ways to minimize the use of hazardous chemicals, possible alternative products, and proper disposal procedures for ordinary household products.

5. The students could organize a city-wide awareness program on the problem of hazardous materials in the home. Through telephone surveys, the magnitude of the problem could be measured and the attitude of the population determined. By means of a carefully prepared brochure the public could be educated about the dangers present in consumer products found throughout the home.

Publicity for the effort could be arranged by organizing a "blue ribbon" panel including the principal, mayor, director of the local water and sewer authority, and other prominent figures to publicly discuss the problem and to suggest solutions.

6. Select activities from the curriculum guide, Toxics in My Home? You Bet! This guide is available from Golden Empire Health Planning Center, 2100 21st Street, Sacramento, California 95818, (916) 731-5050. Cost of the curriculum is $6.50. A postage and handling charge of $3.50 must accompany all mail orders. Learning activities in the curriculum are appropriate for grades 9-12.

[Ed. Note: This is a very impressive program which usually produces excellent student participation. Appropriate for any level HS class. It develops acute consumer awareness.**]**

7. Discuss chemical incidents featured on local radio or TV programs. Have students write short news stories on the incident which incorporate a discussion of the chemistry involved.

By improving the students' awareness of chemical concerns, the high school chemistry teacher has provided one of the most important and long lasting effects of the chemistry experience. Relevance, a much overused word, has rarely been associated with chemistry courses. By the procedures listed above, this unfortunate characterization will be changed for the better.

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Ace Glass, Inc., P.O. Box 688. Vineland, NJ 08360
1-609-692-3333

Bolab, P.O. Box N, Lake Havasu, AZ 86403, 1-602-855-0159,
Suppliers of plastic Beral pipets. (Model #BB111
SED1; $14./500)

Chemglass,3861 Mill Road, Vineland, NJ 08360
1-800-843-1794

Corning Glass, Corning, NY 14831
1-800-222-7740

Kontes Glass, P.O. Box 729, Vineland, NJ 08360
1-800-223-7150 suppliers of the Williamson Kit

National Scientific Company, 5855-L Oakbrook Parkway, Norcross, GA
30093, 1-800-332-3331, suppliers of plastic transfer
(Beral) pipets

IX. PHONE NUMBERS

Aldrich Catalog
1- 800- 231-8327

American Chemical Society Library Services
Ms. Maureen Matkovioch, Head
Health and Safety Referral
(202) 872-4515

Central Scientific Company (312) 451-0150
Hazardous Chemicals Data Book Cat. #31975
Cost $119.00 Contains 1100 MSDS

Chemical Emergency Preparedness Hotline
1-800-535-0202

Chemical Manufacturers Association (CMA)
Chemical Referral Center
(Non-emergency chemical information)
1-800-CMA-8200 (M - F 8AM - 9PM EST)

Chemical Transportation Emergency Center "**CHEMTREC**"
24 hr. Emergency information for chemical spills
from transportation accidents
1-800-424-9300

Department of Transportation (DOT) Emergency Hazard Information
1-800-752-6367

Duke Poison Control Center
1-800-672-1697

DuPont Chemical Hotline
1-800-441-9475

EPA (US Environmental Protection Agency) Hotline
(202) 382-4770

EPA Waste Disposal Firm Information and
Hazardous Waste Hotline
1-800-424-9346

Flinn Catalog
(312) 879-6900

Lab Safety Supply
Nationwide supplier of safety supplies
1-800-356-0783

Mallinkrodt Access to Lab Chemical Data
The system is called "**Lab Link**" and through
an 800 number, teachers can obtain information
concerning lab chemicals. The computer user
needs a 1200 Baud modem, even parity, 7 data + 1 stop.
Dial 1-800-522-5465 Log on: LABLINK Password: Quality

National Institute of Occupational Safety and Health (NIOSH), for
non-emergency technical information and to request health
hazard evaluations 1-800-35-NIOSH

National Science Teachers Association "Science Safety Conference",
on the 'ScienceLine' remote bulletin board system.
300/1200/2400 baud, (202) 328-5853 or 265-4496.
System operator voice line (202) 328-5800 x57

Natural Resources Defense Council
INFOLINE on Household Chemicals
1-800-648-6762

NC Department of Public Instruction, Division of Science
(919) 733-3694

NC Division of Emergency Management
(919) 733-3867

NC Division of Labor (OSHA)
current listing of hazardous materials
(919) 733-2486

NC Division of Science
(919) 733-3694

NC Governor's Waste Management Board
(919) 733-9020

NC Pollution Prevention Pays Program
(919) 733-7015

NC Solid and Hazardous Waste Technical Assistance
(919) 733-2178

OSHA (US Occupational Safety and Health Administration)
(202) 523-6091

Public Chemical Information Center
1-800-828-4445

TSCA (Toxic Substances Control Act)
1-800-424-9065

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XIII. POSTLUDE

From the material discussed in this book, it should be clear that all of the necessary information on how to reduce hazardous waste from high school chemistry laboratories is not now available. This is a rapidly developing field. More teachers and administrators must take an active and personal role before major advances will be made.

The regulatory climate will very likely become more strict in the next several years. There will be ever increasing regulations, tighter budgets, and other pressures to reduce the amounts of material being discarded. Students and their families are becoming increasingly aware of the problems associated with the mishandling of hazardous materials. Court decisions will also be delivered that will more clearly assess the persons responsible for accidents in educational institutions. More information will continue to issue from the toxicology laboratories demonstrating new and unforseen hazards of chemicals in common use.

How is the high school teacher to cope? Only by becoming conversant with all of the issues mentioned above. The Universities will be under greater pressure to treat these subjects in the science education curriculum to prepare new teachers. The Universities will also offer in-service workshops for teachers already in the classroom. None of the issues will just 'go away'. They must all be treated explicitly.

The one sure thing learned from this exercise is that the scale of high school laboratory experimentation can be easily reduced by switching to micro-scale experiments. This change will greatly reduce all of the problems associated with chemical experimentation, and the quantities of hazardous waste in particular. It will also permit the increased "hands-on" laboratory experience that all students need to properly understand science.